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THEORIES OF THE EARTH FROM DESCARTES TO CUVIER: NATURAL ORDER AND HISTORICAL CONTINGENCY IN A CONTESTED TEXTUAL TRADITION

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THEORIES OF THE EARTH FROM DESCARTES TO CUVIER:
NATURAL ORDER AND HISTORICAL CONTINGENCY
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A Dissertation APPROVED FOR THE
DEPARTMENT OF THE HISTORY OF SCIENCE

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- Kenneth L. Taylor (middle)
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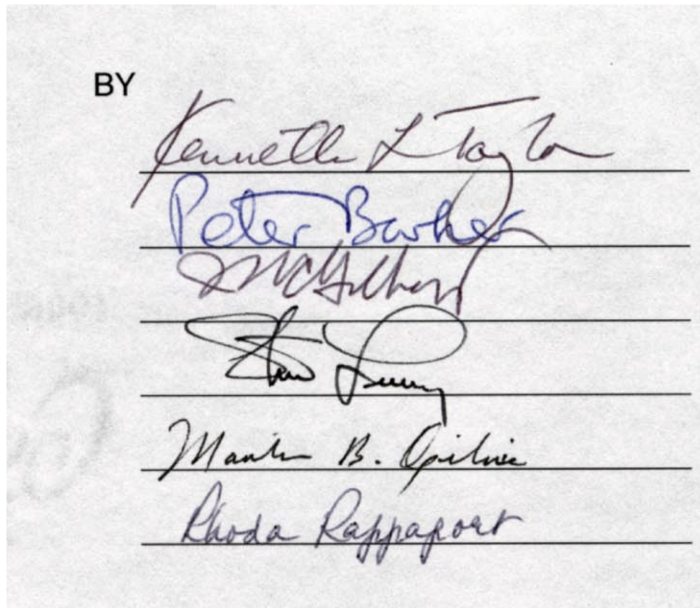

FIGURE 1. Filippo Angelico Becchetti, *Teoria Generale della Terra*, 1782 (frontispiece). Courtesy Linda Hall Library.

To my parents,

Jack and Sue Magruder

Acknowledgments

> Give me Vesuvius' crater for an inkstand! Friends, hold my arms![1]
>
> Herman Melville, *Moby Dick*

To write about Theories of the Earth with historical sympathy at times creates a temptation to write like them, in order faithfully to transmit the "comprehensiveness of sweep" by which they toured "throughout the whole universe, not excluding its suburbs." For constant encouragement to write about them despite the never-ending task of encompassing the whole universe of mighty books known as Theories of the Earth, along with their suburbs, I thank Professor Kenneth L. Taylor. His example of diligent scholarship and careful historical reflection both inspired me and proved difficult to follow. Let none of his col-

[1] The immediate context of Melville's quote, equally apt for Theories of the Earth, serves to introduce Ishmael's remarks on fossil whales: "One often hears of writers that rise and swell with their subject, though it may seem but an ordinary one.... Give me Vesuvius' crater for an inkstand! Friends, hold my arms! For in the mere act of penning my thoughts of this Leviathan, they weary me, and make me faint with their out-reaching comprehensiveness of sweep, as if to include the whole circle of the sciences, and all the generations of whales, and men, and mastodons, past, present, and to come, with all the revolving panoramas of empire on earth, and throughout the whole universe, not excluding its suburbs. Such, and so magnifying, is the virtue of a large and liberal theme! We expand to its bulk. To produce a mighty book, you must choose a mighty theme. No great and enduring volume can ever be written on the flea, though many there be who have tried it." Herman Melville, *Moby Dick or, The Whale,* ch. CIV, ed. Alfred Kazin, Riverside Editions, ed. Gordon N. Ray (1851; rpt. Boston: Houghton Mifflin Company, 1956), 350.

leagues blame him for unwise renegade views of one of his students. I trust they, like Professor Taylor, will charitably apply Bacon's dictum, "Truth emerges more readily from error than from confusion."[2] I thank professors Marilyn Ogilvie, Steve Livesey, and Peter Barker of the History of Science Department for many conversations in which they generously offered encouragement and constructive criticism, the treasured gifts of rare teachers. Rhoda Rappaport, Professor of History at Vassar College *emerita*, saved me from many blunders and provided stimulating comments, although my work adds little to her magisterial scholarship. I thank Charles Gilbert, Professor of Geology and Geophysics at the University of Oklahoma, for playing an important role as a scientific reader. Of course, no member of my committee is responsible for the shortcomings that remain.

Crucial financial support for this research was provided by the University of Oklahoma and History of Science Department in the form of a Centennial Scholarship and graduate assistantships. The History of Science Collections of the University of Oklahoma and Linda Hall Library always provided convenient access to their impressive holdings. For the former I thank the late Duane H. D. Roller, Professor Marcia Goodman, and Marilyn Ogilvie. Bruce Bradley and Bill Ashworth kindly facilitated my research in Kansas City, which was made possible by a 1997 Fellowship from the Friends of Linda Hall Library. I also thank the librarians at Truman State University for capable interlibrary-loan service and convenient access to the Landmarks of Science microprint series.

For initially enchanting me with his vision of Theories of the Earth, I thank the late Jacques Roger, whom I never met but who nevertheless taught me by his writings to appreciate this fascinating genre. Along with Professor Taylor's unexcelled mentorship and Roger's corpus, the justly acclaimed work of Martin Rudwick and the prodigious scholarship of David Oldroyd have taught me far more, of course, than I can ever repay to others. Let no one mistake occasional criticisms of these enduring mountains for lack of respect; rather, from them I learned how to search for pebbles along the shore.

Like other practiced teachers I ungrudgingly recognize that learning depends crucially upon the qualities of one's fellow students, and in my case I have been fortunate. I thank my

[2] Quoted in Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2d ed. (Chicago: University of Chicago Press, 1970), 18.

fellow graduate students at the University of Oklahoma who have endured long conversations about my research, especially Aaron Poffenberger, Mike Keas, Shawn Smith, Mark Eddy, and Kuang-Tai Hsu. I thank various Fellows in the History of Science Department who graciously encouraged the first fruits of a beginning scholar, particularly Eric Meyer, Erik Sageng, Jole Shackelford, Pam Gossin, and Joy Harvey. The interest shown by Michael Barfield and Aaron Poffenberger, apparently unfeigned during endless late-night discussions, was a constant delight which often clarified my thinking and facilitated its clearer expression.

With pleasure I affirm an unutterable appreciation due my family. To my parents, my first and most important intellectual companions, whose lifelong habits of critical discussion and encouragement have enabled me to discover myself and pursue the life of a scholar; this is for you. To Rachel and Hannah, who have waited patiently for this to be completed; for Susanna who is yet to realize how her life may change as a result. Above all, to Candace without whose sustaining friendship not a single year of my graduate work would have been possible. Thank you all for believing it was worth the sacrifice.

The hospitality of family and friends has been as generous as it was vital. Aside from my parents to whom my debts are astonishingly incalculable, Bob Wood opened his home in Kansas City during my fellowship at Linda Hall Library; Joe and Dorothy Potter provided the use of their home in Estes Park for a critical month of writing in winter 1999; and Douglas and Venus Seewald welcomed me to their home in Norman for my final spring semester in residence.

For assistance with all matters photographical I thank Bill Ashworth and Bruce Bradley at Linda Hall Library, and Marilyn Ogilvie and Sylvia Patterson at the History of Science Collections of the University of Oklahoma. Michael Barfield repeatedly provided indispensable assistance with digital imaging. This project has been technology-dependent throughout, so it is appropriate to acknowledge the most important hardware and software: Apple's iMac appeared just in time to allow me to process hundreds of images in Adobe Photoshop with acceptable speed. Also essential for the present form of this study is Adobe FrameMaker software which uniquely combines the features of page-layout and word-processing applications.

Finally, I would like to console any friends and teachers who may have expected the worth of the product to be proportional to the time of preparation. It is comforting to me

that the only Theorist whose work still engenders nearly universal admiration felt much the same about his writing and, customarily, said it best.[3] However, to you I offer the following confession, in the spirit of a multitude of Theorists whom I have come to appreciate with a greater understanding and respect:

> Finally, it was stated at the outset, that this system would not be here, and at once, perfected. You cannot but plainly see that I have kept my word. But I now leave my cetological System standing thus unfinished, even as the great Cathedral of Cologne was left, with the crane still standing upon the top of the uncompleted tower. For small erections may be finished by their first architects; grand ones, true ones, ever leave the copestone to posterity. God keep me from ever completing anything. This whole book is but a draught—nay, the draught of a draught. Oh, Time, Strength, Cash, and Patience.
>
> Herman Melville, *Moby Dick*, ch. XXXII[4]

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3 See Nicolaus Steno's dedication of the *Prodromus* (1669) to the Grand Duke of Tuscany. Steno began an eloquent series of reflections on the nature of research and discovery with the analogy of mountain travel: "While travellers in unknown territories hasten over rough mountain tracks towards a city on a mountain top, it often happens that they judge the city, at first sight, to be close to them; constantly, numerous twists and turnings along the route delay their hope of arrival to the point of weariness, for they see only the nearest peaks; in fact, those things hidden by the said peaks, the heights of hills, the depths of valleys, or the level of plains, whatever they may be, far exceed their conjectures, and they, deceiving themselves, estimate the intervening distances from their own desires." *Steno: Geological Papers,* trans. Alex J. Pollock, ed. Gustav Sherz (Odense: Odense University Press, 1969), 136–139.

4 Herman Melville, *Moby Dick,* ed. Alfred Kazin, 125.

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References to figures reproduced in the dissertation are not italicized (e.g., Figure 1), but references to original illustrations as they were labelled in the primary sources themselves are italicized (Burnet's *figure 1*). A very few illustrations are repeated in the text for readers' convenience.

Figures are not reproduced to scale. All reproductions are courtesy of the History of Science Collections of the University of Oklahoma (HSCI) or the Linda Hall Library in Kansas City, Missouri (LH) as indicated in each legend unless otherwise noted.

Abstract

Jacques Roger argued that Theories of the Earth contributed to the development of historical sensibilities in natural science. This dissertation establishes the need to positively reassess a modest form of his "Relevance Thesis."

Part I explores the character of Theories of the Earth as a contested textual tradition. A *textual tradition* is delineated by internal and external textual criteria rather than defined as a mentality or metaphysical world-view. As a textual tradition Theories of the Earth were contingently established with Descartes and the controversies over Burnet and sustained through the generation of Cuvier, rather than being the inexorable expression of post-Copernican cosmology, of a metaphysical world-view, or of a pre-geological genre of non-empirical speculation. Theories of the Earth were a *contested* textual tradition in which experts representing diverse technical traditions participated rather than a unified, conceptually-continuous, intrinsically-coherent research program.

Part II sketches a rough portrait of Theories of the Earth based upon a "reading" of their visual representations of the globe. Chapter 4 argues that in addition to being of interest in their own right, global illustrations provide a suitable subject for analysis in the terms of textual traditions. At the same time they serve as a more representative sample of what Theories of the Earth were about than would a survey of alleged key concepts. Chapter 5 provides a systematic reading of the illustrations involved in the establishment of the contested textual tradition. Chapter 6 surveys snapshots of various technical transformations of the tradition.

Parts I and II together suggest that the language of biblical idiom fostered the expression of historical sensibilities in the tradition, although such idiom was never an essential characteristic of Theories of the Earth. Hexameral idiom facilitated the interpretation of Earth history as an ordered succession of events (prehuman, sometimes historically-contingent, not necessarily ancient) on the basis of the coordinated reading of a variety of kinds of empirical evidence. This supports a modest form of Roger's Relevance Thesis, consistent with other studies emphasizing the significance of historical scholarship, mineralogy, and paleontology for the development of historical sensibilities.

Key words:
Theory of the Earth, Theories of the Earth, early geology, textual tradition, hexamera, hexaemera, hexameron, meteorology, rhetoric of science, hermeneutics, popular science, public sphere, concordism, Genesis, contingence, contingency, creation, providence, history, visual representation, cosmology.

Introduction

"The Theory of the Earth was not a negligible accident; neither in the history of the sciences in general, nor in the history of the sciences of the Earth in particular. By imposing the idea of a history of nature, it has extended its own influence well beyond the history of the sciences." Jacques Roger

Theories of the Earth *"proposed models or 'systems' for the causal development of the whole earth, but they were deeply ahistorical.... What all these 'systems' lacked was any significant element of the contingency that would have marked a truly geohistorical narrative."* Martin J. S. Rudwick

The textual tradition of Theories of the Earth stands in need of comprehensive reassessment. Part I, "From Cosmology to Geology: Reassessing Theories of the Earth," provides an overview of historiographical issues that underlie contrary interpretations past and present. What is a "Theory of the Earth"? What were Theories of the Earth about? What kinds of evidence did their authors regard as most important? To what extent were their explanations of the Earth historical in character?

The textual tradition of Theories of the Earth has always been controversial; many of the terms and definitions needed to pose basic questions about it remain problematic. For example, historians disagree markedly over whether particular actors from Steno or Hooke to Hutton or Cuvier were indeed Theorists of the Earth. Much of this disagreement results from the fact that Theories of the Earth are usually regarded as a protoscientific metaphysical or theological genre of thought. Chapter 1, "Delineating a Textual Tradition," shows that conventional perspectives are untenable and lead to paradoxes and contradictions that are resolved only when Theories of the Earth are regarded as a contested textual tradition. These arguments for Theories of the Earth are extended with respect to seventeenth-century changes in cosmology and the early nineteenth-century emergence of historical geology in Chapter 2, "On the Boundaries of Cosmology," and Chapter 3, "On the Edge of Geology."

Moreover, in making the methodological argument that Theories of the Earth should be understood as a textual tradition rather than in terms of more familiar disciplinary categories, the three chapters of Part I survey a variety of textual and technical contexts appropriated by Theories of the Earth, including classical antiquities, historical scholarship, meteorology and mineralogy. Chapter 1 explains why this preliminary study selectively but not arbitrarily concentrates on the convergence with Theories of the Earth of two early-modern textual traditions: visual illustrations of the Earth in the form of global sections and views; and hexameral idiom, or the specific words, phrases, language, and conceptual framework of the first chapter of Genesis, particularly the third day.

Finally, as the contrasting epigraphs suggest, current historiography is markedly divided about whether Theories of the Earth were relevant to the development of temporal sensibilities. The three chapters of Part I begin to make the case that it is plausible to positively reassess a modest form of Roger's Relevance Thesis. If Theories of the Earth are recognized as a contested textual tradition then the agenda of sharply demarcating between Theories of the Earth and other texts (as in the case of Cuvier) becomes irrelevant, and many of the objections to a Relevance Thesis dissipate. This argument is extended in Part II by surveying how writers of Theories of the Earth appropriated hexameral idiom and deployed global illustrations.

Part II, "Global Visions," surveys various Theories of the Earth by analyzing their global sections, global views, and related visual representations. Global illustrations provide a representative sample of what Theories of the Earth were about while establishing the contours of a dialectical tradition of inquiry and debate. The analysis does not begin with observer categories stipulating the nature of "historical sensibility" nor with a disembodied definition of a "Theory of the Earth." Rather, the works themselves are inspected in an effort to constrain interpretation by actors' categories—in this case, as they were visually expressed and, as it turns out, with particular attention to hexameral idiom. The interpretation of global sections and views suggests that the development of historical sensibilities was a significant aspect of a heterogenous tradition.

Chapter 4, "Theories of the Earth and Visual Representations," explores the precedents for global sections and views provided by cosmic sections, and notes the pervasive expression of hexameral themes and idiom in such visual representations. Without ignoring other equally important early-modern traditions such as historical scholarship and meteorology, one aspect of biblical interpretation becomes prominent in the analysis of the global sections and views and is given special attention as a representative topic: rather than trying to discuss the significance for Theories of the Earth of the book of Genesis as a whole, nor focusing on the influence of the biblical account of the Deluge, nor even surveying interpretations of the creation week, or *hexameron*, in its entirety, Part II pays special attention to the uses to which Theorists put their interpretations of the third day of creation, according to which the waters were gathered together and dry land appeared. Contested interpretations of the third day affected the ways many Theorists developed evidence from other sources and shaped their sensibilities regarding the history of the Earth.

Chapter 5, "Textual Assimilation: The Sacred Theory of Burnet," focuses on the most significant Theory of the Earth in the seventeenth century which established a variety of visual conventions for global sections and views. Controversies over the works of Descartes and Burnet initially constituted the textual tradition, and in relation to some reflections on the correspondences between visual and verbal rhetoric the conclusion of this chapter contrasts their epistemic styles for obtaining knowledge of the Earth's past.

Chapter 6, "Technical Naturalization: Portraits of a Dynamic Tradition," sketches a portrait of the transforming tradition on the basis of snapshots of other global sections and views employed in Theories of the Earth to the early nineteenth century. The emerging picture displays a panorama of perspectives offered by Theories of the Earth regarding the formation and history of the Earth.

The Epilogue summarizes the case for a reassessment of the tradition of Theories of the Earth. Rather than providing the needed reassessment of Theories of the Earth and the development of historical sensibilities, the episodes and vignettes analyzed in this study only provide a point of departure, in part by showing that fundamental questions remain unresolved despite the work of careful scholars who have immeasurably enriched our understanding, albeit with partial and often conflicting views. Although the late Jacques Roger insisted upon the significance of Theories of the Earth, as in the epigraph translated above, they are usually dismissed as irrelevant to the development of historical sensibilities about the Earth.[1] A more typical assessment is that Theories of the Earth "proposed models or 'systems' for the causal development of the whole earth, but they were deeply ahistorical.... What all these 'systems' lacked was any significant element of the contingency that would have marked a truly geohistorical narrative."[2] Similarly, despite Roger's further claim that biblical culture contributed to the emergence of directionalist sensibilities, the hexameral tradition is usually regarded as more of a shackle to the development of historical perspectives: "Perhaps the principal obstacle to the growth of cultural history in the 16th century was the hexameral literature."[3] Yet the Theory of the Earth tradition is vast, and conventional generalizations on all sides are hazardous. To remove a few obstacles to an historically-adequate portrayal of the Theory of the Earth tradition is the chief concern of this essay, where it is argued that Theories of the Earth significantly shaped the framing and expression of ideas regarding historical contingency in the Earth's past.

[1] "Ni dans l'histoire des sciences en général ni dans l'histoire des sciences de la Terre en particulier, la théorie de la Terre n'a été un accident négligeable. En imposant l'idée d'une histoire de la nature, elle a même étendu son influence bien au-delà de l'histoire des sciences." Jacques Roger, "La théorie de la terre au XVIIe siècle," *Revue d'Histoire des Sciences*, 1973, 26: 48.

[2] Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the reconstruction of geohistory," *Earth Sciences History* 15 (1996): 27.

[3] William B. Ashworth, Jr., "The Sense of the Past in English Scientific Thought of the Early 17th Century: The Impact of the Historical Revolution" (Ph.D. dissertation, University of Wisconsin-Madison, 1975), 41-42. I cite Ashworth's statement here not to dispute its validity in its narrowly-defined field of reference, but to illustrate a widespread historiographical sentiment; cf. footnote 132 on page 68.

PART I

FROM COSMOLOGY TO GEOLOGY: REASSESSING THEORIES OF THE EARTH

The famous portrait of our planet as a single ball, swirling with cloud, taken by Apollo astronauts on their way to the Moon, is in no way a geological view. It is too distant, too complete, too unified—indeed, too much like the Moon itself. It is therefore something else....

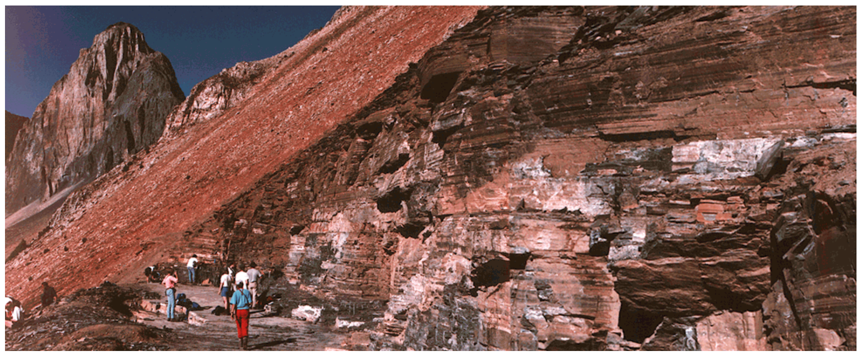
Scott L. Montgomery, *The Moon and the Western Imagination*

FIGURE 2. Earthrise from Moon, Apollo 8. Courtesy NASA/JPL.

CHAPTER 1

Delineating a Textual Tradition

FIGURE 3. Burgess Shale exposure in the Walcott quarry, Yoho National Park, near Field, British Columbia, Canada. Photograph © 1995 by Andrew MacRae, "Burgess Shale Fossils" (*www.geo.ucalgary.ca/~macrae/Burgess_Shale/*), accessed July 5, 1999, used with permission.



§ 1. Theories of the Earth and the History of Nature

In *Wonderful Life*, at one time the second-favorite book of professional geologists in the United States, Stephen Jay Gould suggests that the unique organisms captured in the Burgess Shale of British Columbia raise significant questions about the history of nature and the nature of history. Paleontological research regarding these fossils, Gould writes, has

> confronted our traditional view about progress and predictability in the history of life with the historian's challenge of contingency—the "pageant" of evolution as a staggeringly improbable series of events, sensible enough in retrospect and subject to rigorous explanation, but utterly unpredictable and quite unrepeatable. Wind back the tape of life to the early days of the Burgess Shale; let it play again from an identical starting point, and the chance becomes vanishingly small that anything like human intelligence would grace the replay.[1]

The relationship between natural order and historical contingency occupying Gould's attention throughout *Wonderful Life* has attracted the scrutiny of many before him—indeed, it was the chief occupation of a tradition of works published in the seventeenth and eighteenth centuries known as Theories of the Earth.[2]

From Aristotle's physics to the chaos theory of the late twentieth century, diverse perspectives of order and disorder in nature have been bound up at the conceptual heart of natural philosophy. Phrases common to historians of science such as "the temporalizing of the Chain of Being"[3] or "from natural history to the history of nature"[4] reflect the intimate relations between perspectives of natural order and visions of the past. Theories of the Earth offer a

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1 Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton and Company, 1989), 14. *Wonderful Life* was second only to Charles Lyell's *Principles of Geology* in the survey of members of the Geological Society of America by D. M. Triplehorn and J. H. Triplehorn, "Geologists Select the Great Books of Geology," *Journal of Geological Education*, 1993, 41: 260-261. Gould's quotation precisely describes "contingent" or "contingency" as used in this study to refer to events which, according to a given historical actor, might have turned out otherwise, are not deducible or fully specifiable in advance, may be rare or unusual, but nevertheless become *intelligible* when considered in retrospect by methods such as historical reconstruction. This definition of "contingent" is analytical rather than an actor's category, and displaces the chance vs. necessity polarity altogether. The word "chance," although often used by historical actors and in *Wonderful Life* synonymously with "contingent," here will be reserved for phenomena which were regarded by a given actor as *unintelligible* due to their apparently random or accidental character. This nescient verdict is consistent with Aristotle's usage of *tyche* in Book II of the *Physics*, although Aristotle defined chance as the cause of what does not regularly occur and therefore regarded rare or unusual events as unintelligible in every case. On the other hand, to affirm the possible intelligibility of rare events and so distinguish between chance and contingency is not idiosyncratic; rather, it is consistent with a long-standing theological usage of *contingere,* about which see Thomas F. Torrance, *Divine and Contingent Order* (Oxford: Oxford University Press, 1981), reprised in Thomas F. Torrance, "Divine and Contingent Order," in *The Sciences and Theology in the Twentieth Century,* ed. A. R. Peacocke (Notre Dame: University of Notre Dame Press, 1981), 81–97. Torrance explores, in patristic theology, how the Incarnation and *creatio ex nihilo* served as two prime exemplars of rare or even unique but nevertheless intelligible (and therefore contingent) events.

2 Relations between natural order and historical contingency continue to attract attention after *Wonderful Life*. In a more recent work offered as a companion piece to *Wonderful Life,* Gould emphasizes a pattern of life history driven by random, nondirectional variation; Stephen Jay Gould, *Full House: The Spread of Excellence from Plato to Darwin* (New York: Three Rivers Press, 1996). Various attempts to reconstruct the Burgess Shale fossils and to interpret their significance after *Wonderful Life* are surveyed in Simon Conway Morris, *The Crucible of Creation: The Burgess Shale and the Rise of Animals* (Oxford: Oxford University Press, 1998). Conway Morris is Professor of Evolutionary Paleobiology at the University of Cambridge and a Fellow of the Royal Society of London. Besides updating Gould's paleontological reconstructions, Conway Morris disputes Gould's arguments for a radical disparity of phyla in the Cambrian period. Conway Morris also claims, in contrast to Gould, that the significance of contingency for evolutionary development is trivial, given genetic and ecological constraints which result in predictable trends marked by pervasive convergence. The interplay of sensibilities regarding the temporal character of natural order, illustrated by Gould's *nondirected* and *historical* perspective and Conway Morris' *directed* and *developmental* or *genetic* sensibility (cf. Table 2 on page 25), is now a perennial feature of scientific and cultural discussion; Simon Conway Morris and Stephen Jay Gould, "Showdown on the Burgess Shale," *Natural History* 107 (1998): 48-53. Such debates touching the history of the Earth rose to prominence in seventeenth- and eighteenth-century Theories of the Earth.

3 Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936), ch. 9, "The Temporalizing of the Chain of Being," 242–287.

panorama of various temporal sensibilities as they developed in early-modern natural philosophy. Seventeenth- and eighteenth-century Theorists of the Earth attempted to provide integrated and comprehensive visions of the Earth's past (and often of its future), incorporating diverse conceptions of the relations between natural order and historical contingency. To do so they reconciled evidence drawn from diverse intellectual fields into global syntheses or grand schemes narrating the life of the Earth. In these works, perspectives of order and disorder in the "history of nature" were explicitly developed, and became *foci* of public disputes and controversies.

Theorists' diverse temporal sensibilities reflect the variety and adaptability of the tradition itself. Consider their diverse occupations—some were natural philosophers, some natural historians, others antiquarians, lawyers, philosophers, physicians, clergymen, diplomats, engineers, chemists, mineralogists, or mining officials. Their philosophical inclinations could be Cartesian, Newtonian, Scholastic, Paracelsian, Stoic, Neoplatonic, Hermetic, Romanticist, not to mention the eclectics of all stripes in between. Theories of the Earth were not just specimens of "natural theology" or "scriptural geology." Theologically they ranged from Catholic to Lutheran to Reformed, rationalist to voluntarist, High Church Anglican to Latitudinarian to apocalyptic millennarian or dissenting enthusiast, Jesuit to Puritan to Unitarian, theist to deist to free-thinking materialist. Politically they numbered monarchists and republicans, radical reformers and social conservatives.

However quaint Theories of the Earth may appear to the modern eye, the tradition was anything but obscure in its own day or, indeed, for nearly two centuries. From roughly 1640 to 1840 over two hundred Theorists of the Earth published their works for general readers in nearly every major country and language of western Europe. Many writers notable for significant accomplishments in other endeavors participated, including René Descartes (1596–

[4] Wolf Lepenies, "De l'histoire naturelle à l'histoire de la nature," *Dix-huitième siècle*, 11 (1979): 175-184; John Lyon and Phillip R. Sloan, eds., *From Natural History to the History of Nature: Readings from Buffon and His Critics* (Notre Dame: University of Notre Dame Press, 1981).

1650), Robert Hooke (1635–1702), Edmond Halley (ca. 1656–1743), Gottfried Wilhelm Leibniz (1646–1716), Carl von Linné (Linnaeus; 1707–1778), Immanuel Kant (1724–1804), Erasmus Darwin (1731–1802), Jean Baptiste Pierre Antoine de Monet de Lamarck (1744–1829), and Georges Cuvier (1769–1832).[5]

On a conceptual level, the only common thread that tied these diverse Theories of the Earth together was an explicit and general concern with natural order and historical contingency regarding the Earth. Theorists presented different pictures of the Earth's past and engaged competing temporal sensibilities. Regardless of the particular topics investigated, many ambitious meta-questions were raised:

- Are patterns of change on this Earth steady-state, cyclic, or directional and sequential?
- What is the tempo of change?
- How old is the Earth?
- To what degree do present configurations of this Earth represent…
  1) lawfully-ordained, causally-determined outcomes predictable from indubitable premises, at least in principle;
  2) uniquely contingent structures nonspecifiable by causal analysis but capable of ordered reconstruction on the basis of empirical and historical investigation; or
  3) the end result of chance events which have left a chaotic heap of ruins?
- What methods of inquiry are best suited to matters of this sort, and of what epistemic character is the knowledge that results?
- What are the natural significance and epistemic implications of rare or unusual events?
- How might terrestrial changes depend on cosmogony and cosmology?
- What roles do divine and human agency play where history and nature converge? What are the roles of general and particular providence in the world, and of what relevance are human actions given a sweeping course of nature?

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5 Bio-bibliographic data illustrating the claims made in the preceding paragraphs may be browsed on the *EarthVisions.net* website (*www.earthvisions.net*). *EarthVisions.net* is an ongoing prosopographical project designed to facilitate research and communication among interested scholars. To date, two hundred Theorists are included, most of whose works are found in the History of Science Collections of the University of Oklahoma or the Rare Books collection of the Linda Hall Library in Kansas City, Missouri. No claims are made for exhaustive coverage (which aim, in any case, is theoretically incoherent given the problems of a demarcationist agenda as I argue below; page 200 and following). Additions, corrections, comments, and other contributions to *EarthVisions.net* are welcomed, and may be submitted online.

Temporal sensibilities also penetrated other areas of natural philosophy and culture, from embryology to cosmology to historiography and political theory, and on occasion, Theorists of the Earth unabashedly explored these areas as well.

The distinguished historian Jacques Roger argued, in what I call his Relevance Thesis, that Theories of the Earth played a critical role in establishing historical ways of thinking about nature:

> The Theory of the Earth was not a negligible accident; neither in the history of the sciences in general, nor in the history of the sciences of the Earth in particular. By imposing the idea of a history of nature, it has even extended its own influence well beyond the history of the sciences.[6]

Despite major departures from some of Roger's historiographical perspectives, the major aim of the entire present argument is to defend a modest form of Roger's Relevance Thesis. That Theories of the Earth were indeed important for the development of historical sensibilities may seem highly improbable, even outrageous, to modern practitioners of the historical sciences who, when first stumbling upon any one of the various Theories of the Earth, might regard it as equally strange a relic from the past as a fossil of the Burgess Shale (Figure 4).[7]

[6] "Ni dans l'histoire des sciences en général ni dans l'histoire des sciences de la Terre en particulier, la théorie de la Terre n'a été un accident négligeable. En imposant l'idée d'une histoire de la nature, elle a même étendu son influence bien au-delà de l'histoire des sciences." Jacques Roger, "La théorie de la terre au XVIIe siècle," *Revue d'Histoire des Sciences*, 1973, 26: 48. This classic article remains the most influential analysis of Theories of the Earth to date, although the Relevance Thesis has been vigorously disputed by Martin J. S. Rudwick, among others (see below, page 346).

[7] The first specimen of *Anomalocaris*, for example, was named the "strange crab" by J. F. Whitreaves in 1892, who thought it resembled a lobster tail. In 1979 Derek Briggs interpreted it as one limb of a large centipede-like crustacean. Later, while excavating an intact but unidentified specimen, Harry Whittington unexpectedly discovered that *Anomalocaris* was one of two specialized front limbs, joined to a mouth assembly that Charles Walcott had previously interpreted as the jellyfish-like *Peytoia*. This extraordinary meter-long predator is now understood as an arthropod which sported several other spectacular features as well. The story of *Anomalocaris* is documented and popularly told, with illustrations, in Gould, *Wonderful Life,* 194–206, and Conway Morris, *Crucible of Creation,* 39-40, 56–59. Beautiful color paintings representing one currently-accepted reconstruction of *Anomalocaris* are featured on Conway Morris' dust-jacket, and in Color Plate 3 (following p. 104). Gould summarizes the difficulties of paleontological interpretation in this case: "All the pieces had finally come together. From four anomalies—a crustacean without a head, a feeding appendage that didn't fit, a jellyfish with a hole in the middle, and a squashed sheet that had bounced from one phylum to another—Whittington and Briggs had reconstructed two separate species of the single genus *Anomalocaris*" (*Wonderful Life,* 201). The anomalies modern readers encounter upon reading Theories of the Earth render them subject to as disparate interpretations as the disassembled remains of *Anomalocaris,* and they are bounced from one cognitive phylum or discipline or mentality to another. The task of reconstructing the tradition of Theories of the Earth in the context of its long-vanished surroundings is as difficult as reconstructing the life of *Anomalocaris* in the Cambrian seas, although it is potentially as relevant to our understanding of the emergence of the historical sciences as is *Anomalocaris* to our understanding of Cambrian evolution.

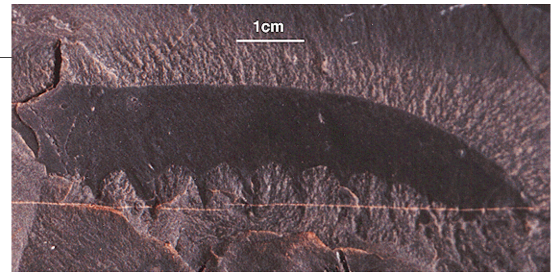

FIGURE 4. *Anomalocaris canadensis,* Burgess Shale, Walcott quarry, Yoho National Park, Canada (feeding appendage; cf. footnote 7). Photograph © 1995 by Andrew MacRae, "Burgess Shale Fossils," (*www.geo.ucalgary.ca/~macrae/Burgess_Shale/*) accessed July 5, 1999, used with permission.

Therefore, to adequately tell the story of Theories of the Earth and their contribution to the development of historical sensibilities reveals a tale of historical contingency not unlike Gould's vision of the development of life. Only vignettes of that tale are told here, though (to paraphrase Gould) they may confront traditional views of scientific progress by showing the development of historical thinking in the natural sciences as a staggeringly improbable series of events, sensible enough in retrospect and subject to rigorous explanation, but utterly unpredictable and quite unrepeatable. Wind back the tape of human history to before the early Theories of the Earth, let it play again from an identical starting point, and the chance might seem vanishingly small that anything like the historical sensibilities of nineteenth-century natural science would grace the replay.[8]

[8] The element of contingency in the development of scientific knowledge is minimized in historiographies of rational reconstruction often favored by philosophers, practitioners, and disciplinary textbooks. Why Theories of the Earth from this standpoint appear as an anomalous or accidental episode in the development of science is considered below, where rational reconstructionist standpoints are rejected, in the sections entitled "Hutton and the Whig Interpretation of Geology," beginning on page 269, and "Lyell and Histories of Scientific Disciplines," beginning on page 280. On the other hand, since Conway Morris minimizes the element of contingency in the development of life by emphasizing genetic and ecological constraints that direct evolutionary pathways along roughly predictable lines (cf. footnote 2), my appropriation of Gould's metaphor may be misread. Let me add the clarifications that by invoking Gould's metaphor of the "tape of life" I wish to imply neither (1) specifically, that Theories of the Earth evolved in a random or entirely unpredictable manner apart from any empirical or natural constraints (and therefore that they should be relegated wholesale to the domain of sociological analysis); nor (2) generally, that models of natural evolution are immediately and unproblematically transferable to the development of human culture (for an incisive historical critique of such moves see Paul Lawrence Farber, *The Temptations of Evolutionary Ethics* [Berkeley: University of California Press, 1994]). My point is simple but essential (and related to the definition of contingency in footnote 1); namely, that Theories of the Earth were neither a necessary nor an accidental episode in the development of science, with the consequence that to understand them requires historical interpretation of contingencies ("sensible enough in retrospect and subject to rigorous interpretation") rather than either rational reconstruction or wholesale social constructivism.

Historians of science have touched on the early development of temporal sensibilities in the natural sciences before the nineteenth century with particular reference to four major intellectual contexts:

- **Cosmology**; including the breakdown of the nondirectionalist, eternalistic Aristotelian cosmos, and the emergence of cyclic or developmental Stoic and Epicurean cosmologies.[9]
- **Natural history**; including New World discoveries, the temporalization of taxonomic methods and teleological views such as "the Great Chain of Being," and a host of causal or genetic theories of embryonic development and species hybridism or transformism.[10]
- **Humanist scholarship**, including classical literary human history, chronology, antiquarianism, archaeology, philology, and the seventeenth-century "historical revolution"; followed by the eighteenth-century dissemination of **German historicism** and romanticism.[11]
- **Biblical culture**, both popular and learned; including hexameral writings, cosmogonical aspects of alchemy, literature on providence and providential history, historical interpretations of astrology, and the theological tradition of *potentia ordinata* and *potentia absoluta* in dialectical tension with "the Great Chain of Being."[12]

Throughout this dissertation we will explore each of these interpretative contexts with respect to Theories of the Earth.

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9 The historiography of cosmology, Theories of the Earth, and historical sensibilities is surveyed in Chapter 2.

10 Timothy Lenoir, *The Strategy of Life: Teleology and Mechanics in 19th-century German Biology* (Dordrecht: Reidel, 1982); Robert J. Richards, *The Meaning of Evolution: The Morphological Construction and Ideological Reconstruction of Darwin's Theory* (Chicago: University of Chicago Press, 1992); Paul Lawrence Farber, *Finding Order in Nature: The Naturalist Tradition from Linnaeus to E. O. Wilson*, Johns Hopkins Introductory Studies in the History of Science, ed. Mott T. Greene and Sharon Kingsland (Baltimore: Johns Hopkins University Press, 2000); and John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Clarendon Press, 1986), chapter 2.

11 Anthony T. Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800* (Cambridge: Harvard University Press, 1991); John D. North, "Chronology and the Age of the World," in *Cosmology, History, and Theology,* ed. Wolfgang Yourgrau and Allen D. Beck (New York: Plenum Press, 1977), 307–333; James Barr, "Why the World was Created in 4004 B.C.: Archbishop Ussher and Biblical Chronology," *Bulletin of the John Rylands University Library* 67 (1985): 575–608; Anthony T. Grafton and Noel M. Swerdlow, "Technical Chronology and Astrological History in Varro, Censorinus and Others," *Classical Quarterly* 35 (1985): 454–465; and Donald J. Wilcox, *The Measure of Time's Past: Pre-Newtonian Chronologies and the Rhetoric of Relative Time* (Chicago: University of Chicago Press, 1987); William B. Ashworth, Jr., "The Sense of the Past in English Scientific Thought of the Early 17th Century: The Impact of the Historical Revolution" (Ph.D. dissertation, University of Wisconsin-Madison, 1975).

12 Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936) as corrected and supplemented by Francis Oakley, *Omnipotence, Covenant, and Order: An Excursion in the History of Ideas from Abelard to Leibniz* (Ithaca: Cornell University Press, 1984); William J. Courtenay, *Covenant and Causality in Medieval Thought: Studies in Philosophy, Theology, and Economic Practice* (London: Variorum, 1984); William J. Courtenay, *Capacity and Volition: A History of the Distinction of Absolute and Ordained Power*, Quodlibet: Ricerche e strumenti di filosofia medievale, no. 8 (Bergamo: Pierluigi Lubrina, 1990); Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994).

However, these four themes are insufficient to capture the origin of historical sensibilities within the Earth sciences. As Table 1 on page 17 suggests, no scholarly consensus exists. The studies summarized in the first half of Table 1 explore various manifestations of historical thinking about the Earth in the seventeenth and early eighteenth centuries. In most general terms, one may oversimplify the development of historical thinking about the Earth with a summary outline of four main options:

- *Eternity* vs. *Decay:* In the midst of great changes in cosmology in the seventeenth century, various arguments that the Earth must have had a beginning were explored against views of the eternity of the world (including nondirectionalist views from traditional meteorology). To many it seemed likely that the Earth had been quite different in past ages and that it remained subject to change through incremental or catastrophic processes, often of decay.
- *Developing Earth:* In the late seventeenth and eighteenth centuries the option of an ancient and progressively developing Earth became more prominent, in addition to eternity and decay.
- *Prehuman Earth:* In the later eighteenth century and the early decades of the nineteenth century a relative consensus was achieved of the existence of vast prehuman ages of the Earth, although various views retained traces of the earlier options.

This far too schematic outline, perhaps more misleading than its heuristic purpose justifies, fails to do justice to the particular studies which may be taken as supporting it to a greater or lesser degree. For example, Cecil J. Schneer points to the "rise of historical geology" in seventeenth-century England, emphasizing the role of the Royal Society of London: "The fusion of historical and antiquarian interests with collecting and classifying of natural objects was to lead to an historical science of the earth. The meetings of the Royal Society were the focus of this interchange."[13] The fusion identified by Schneer exemplifies the recurring, overlapping

[13] Cecil J. Schneer, "The Rise of Historical Geology in the Seventeenth Century," *Isis*, 1954, 45: 263. Schneer comments (p. 257): "Stirred by their inchoate curiosity about the past, they looked for material evidences, antiquities, minerals, the accounts of changes of the courses of rivers, and topographical speculations. The men who began these speculations were at first collectors, and the only link in their minds between the coins they dug up and the fossils they described was that both could be put into a cabinet. As they collected curiosities for their cabinets, in the same spirit they made drawings of barrows and ruins and recorded the archaic speech of Wales and Brittany. This feeling for the past, this sense of process and change, was the climate in which geological science began."

themes of natural history and humanist scholarship (two of the four contexts noted above). Practices associated with textual scholarship were prominent in natural history, as naturalists regarded evidence and questions obtained from antiquities, philology, ancient geography, and classical literature as most significant for their own endeavors. Naturalists often "read" evidence from field observations and cabinet specimens in tandem with textual evidence and antiquarian artefacts such as coins and monuments. Schneer illustrates his thesis with a famous passage from Hooke's *Works* treating extraneous fossils as the coins and monuments of long-lost ages of Nature:

> The doctrine aimed at, is, the Cause and Reason of the present Figure, Shape and Constitution of the Surface of the Body of the Earth,.… Now, because when we look into Natural Histories of past Times, we find very few, if any, Footsteps of what alterations or transactions of this Nature have been performed, we must be fain to make use of other helps than what Natural Historians will furnish us with, to make out an account of the History thereof: Nor are there any Monuments or Medals with Literal, Graphical, or Hieroglyphical Inscriptions that will help us out in this our Inquiry, by which the writers of Civil Histories have of late Years been much assisted from the great curiosity of modern Travellers and Collectors of such curiosities.… If in digging a Mine, or the like, an artificial Coin or Urne, or the like Substance be found, no one scruples to affirm it to be of this or that Metal or Earth he finds them by trial to be of: Nor that they are Roman, Saxon, Norman, or the like, according to the Relievo, Impression, Characters, or Form they find them of. Now these Shells and other Bodies are the Medals, Urnes, or Monuments of Nature whose Relievoes, Impressions, Characters, Forms, Substances, &c. are much more plain and discoverable.… to correct natural Chronology… nor will there be wanting Media or Criteria of Chronology.…[14]

[14] Robert Hooke, *The Posthumous Works of Robert Hooke … Containing his Cutlerian Lectures, and other Discourses, Read at the Meetings of the Illustrious Royal Society* (London: Publish'd by Richard Waller; Printed by Sam. Smith and Benj. Walford, 1705), 334-335. Hooke's lectures are available in facsimile reprint as *Robert Hooke, Lectures and Discourses of Earthquakes and Subterraneous Eruptions*, History of Geology Series (Ayer Publishing, 1978). In a painstaking analysis, Rhoda Rappaport tabulated Hooke's lectures in chronological order; Rhoda Rappaport, "Hooke on Earthquakes: Lectures, Strategy and Audience," *British Journal for the History of Science* 19 (1986): 129–146. Hooke's lectures are reprinted according to Rappaport's chronology in Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford: Oxford University Press, 1996). The antiquarian context of this passage and other aspects of Hooke's work are considered in Rhoda Rappaport, "Borrowed Words: Problems of Vocabulary in Eighteenth-Century Geology," *British Journal for the History of Science* 15 (1982): 27–44, hereafter Rappaport, "Borrowed Words"; and Kirsten Birkett and David Oldroyd, "Robert Hooke, Physico-Mythology, Knowledge of the World of the Ancients and Knowledge of the Ancient World," in *The Uses of Antiquity: The Scientific Revolution and the Classical Tradition,* ed. Stephen Gaukroger, Australasian Studies in History and Philosophy of Science, ed. R. W. Home, no. 10 (Dordrecht: Kluwer Academic Publishers, 1991), 145–170. Hooke is discussed below in "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354.

Ellen T. Drake likewise emphasizes the role of Robert Hooke, emphasizing that he advocated the reality of extinction, the organic origin of fossils, and practiced rudimentary methods of fieldwork on the Isle of Wight.[15] Although Hooke's efforts remain of central importance for assessing the geohistorical sensibilities of the Royal Society, a number of other individuals have been studied as well. Yushi Ito argues that the Royal Society seriously pursued geological inquiries in the seventeenth century so that it is incorrect to speak of a delayed "scientific revolution" with respect to the Earth sciences.[16] Edmond Halley held to a long duration for the age of the Earth, and Allan Chapman documents Halley's use of historical evidence to corroborate evidence from astronomy and natural philosophy.[17] In an extensive monograph, Joseph Levine probes the temporal sensibilities relating the habits of antiquarianism, classical history, and natural history collecting in the work of John Woodward.[18]

Emphasizing developments on the continent, Gordon Herries-Davies defines the "Stenonian Revolution" as the development by Nicolaus Steno of an essentially historical way of thinking about the Earth.[19] Kennard Bork discerns in early eighteenth-century Theorists

[15] Numerous earlier studies by Drake are synthesized and updated in Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford: Oxford University Press, 1996); see also Ellen Tan Drake and Paul D. Komar, "Speculations About the Earth: The Role of Robert Hooke and Others in the 17th Century," *Earth Sciences History* 2 (1983): 11–16, and the response by G. Ranalli, "Speculations About the Earth: The Role of Robert Hooke and Others in the 17th Century: A Discussion," *Earth Sciences History* 3 (1984): 187.

[16] Yushi Ito, "Earth Science in the Scientific Revolution" (Ph.D. dissertation, University of Melbourne, 1985).

[17] Allan Chapman, "Edmond Halley's Use of Historical Evidence in the Advancement of Science," *Notes and Records of the Royal Society of London* 48 (1994): 167–191.

[18] Joseph M. Levine, *Dr. Woodward's Shield: History, Science, and Satire in Augustan England* (Berkeley: University of California Press, 1977). Levine muses (pp. 278–279): "Thus Cuvier was merely using and improving the method of natural history which Dr. Woodward and his fellows in the Royal Society had already begun to employ. If he was extending it to new territory with wonderful results, it was nevertheless without altering any of their underlying assumptions about the nature of the world. He was still developing a 'Theory of the earth'.… The method of the antiquaries had been right; only their comparisons were too circumscribed."

[19] Gordon L. Herries-Davies, "The Stenonian Revolution," in *Rocks, Fossils and History,* ed. Gaetano Giglia, Carlo Maccagni and Nicoletta Morello (Firenze: Edizioni Festina Lente, 1995), 45–49. Herries-Davies affirms that (p. 48) "It was Steno who, in the modern world, first demonstrated that rocks, minerals, fossils, and landforms are possessed of geohistorical significance," and concludes (p. 49) "It is the Stenonian Revolution which has enabled modern geology to assume its essentially historical character." Steno's works also had a marked influence on the development of geological thought in the Royal Society, including the works of Hooke and Woodward; V. A. Eyles, "The Influence of Nicolaus Steno on the Development of Geological Science in Britain," *Acta Historica Scientiarum Naturalium et Medicinalium* 15 (1958): 167–188, and Remacle Rome, "Nicolas Sténon et la Royal Society of London," *Osiris* 12 (1956): 244–268.

such as Louis Bourguet and Élie Bertrand the historical explorations of early paleontologists.[20] Just as Phillip Sloan makes an extended case for Buffon's temporalization of the species concept, so Jacques Roger and others argue for Buffon's significance in the development of a directionalist sense of Earth history.[21] Paolo Rossi discerns in the historical philosophy of Vico the discovery of deep time and the divergence between human and natural time scales.[22] In the most detailed and comprehensive study to date, Rhoda Rappaport concludes that geological thinking in the century before Buffon developed as an emerging technical discipline which was profoundly shaped by the habits and methods of historical scholarship.[23] More general interpretations of the development of historical sensibilities in early Theories based upon cosmology and the mechanical philosophy are discussed in Chapter 2. Chapter 3 explores the relations between Theories of the Earth and the emergence of geology with respect to the recognition of a long prehuman geohistory.

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[20] Kennard Baker Bork, "Élie Bertrand (1713-1797) sees God's Order in Nature's Record: The 1766 *Recueil de Divers Traités sur l'Histoire Naturelle*," *Earth Sciences History* 10 (1991): 73–88; Kennard Baker Bork, "Cross-channel currents: Eighteenth-century French language responses to British Theories of the Earth," *Histoire et Nature: Cahiers de l'Association pour l'Histoire des Sciences de la Nature* 19-20 (1981–1982): 37–49; and Kennard Baker Bork, "The Birth of Paleontology in France: 1700–1750," *Journal of the Scientific Laboratories, Denison University* 54 (1973): 65–78.

[21] Buffon's long-recognized importance for the development of transformist views has been superbly analyzed in the work of Jacques Roger and Phillip R. Sloan: Phillip R. Sloan, "From Logical Universals to Historical Individuals: Buffon's Idea of Biological Species," in *Histoire du concept d'espèce dans les sciences de la vie,* ed. Jacques Roger and M. L. Fischer (Paris: Fondation Singer—Poltyac, 1987), 100–140; Phillip R. Sloan, "Buffon, German Biology, and the Historical Interpretation of Biological Species," *British Journal for the History of Science* 12 (1979): 109–153; Phillip R. Sloan, "The Buffon-Linnaeus Controversy," *Isis* 67 (1976): 356–375; Jacques Roger, *Buffon: Un Philosophe au Jardin du Roi* (France: Librairie Arthème Fayard, 1989); Jacques Roger, *Buffon: A Life in Natural History,* trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997). For Buffon and Earth history see Jacques Roger, "The Cartesian Model and Its Role in 18th-century Theory of the Earth," in *Problems of Cartesianism*, ed. Thomas M. Lennon (Kingston: McGill-Queen's University Press, 1982), 95–112; and Jacques Roger, "La théorie de la terre au XVIIe siècle," *Revue d'Histoire des Sciences* 26 (1973): 23–48.

[22] Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico*, trans. Lydia G. Cochrane (Chicago: University of Chicago Press, 1984), originally published as *I segni del tempo: Storia della terra e storia delle nazioni da Hooke a Vico* (Milano: Giangiacomo Feltrinelli Editore, 1979). Similar themes are emphasized by a number of other studies, including Claude C. Albritton, Jr., *The Abyss of Time: Changing Conceptions of the Earth's Antiquity after the Sixteenth Century* (San Francisco: Freeman Cooper Publishers, 1980); Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge: Harvard University Press, 1987); and Francis C. Haber, *The Age of the World: Moses to Darwin* (Baltimore: Johns Hopkins University Press, 1959).

[23] Rhoda Rappaport, *When Geologists were Historians, 1665–1750* (Ithaca: Cornell University Press, 1997), hereafter Rappaport, *When Geologists were Historians*; Rappaport, "Borrowed Words."

TABLE 1. Origins of Historical Sensibilities in the Earth Sciences

Critical Time and Place	Key Figures or Events	Studies
17th-century England	Royal Society of London Robert Hooke Edmond Halley John Woodward	Cecil J. Schneer, Ellen T. Drake, Rhoda Rappaport, Ito Yushi, Joseph Levine, John Greene, Gordon Herries-Davies
17th-century Europe	Nicholas Steno, "The Stenonian Revolution"	Gustav Scherz
Early to mid-18th-century: France, Italy, Switzerland	Academie Royale, Bourguet, Bertrand, Boulanger, Desmarest, Buffon	Rhoda Rappaport, Kennard Bork, François Ellenberger, Kenneth L. Taylor, Jacques Roger, Phil Sloan
Late 18th-century: Germany, Sweden, Scotland	Abraham Gottlob Werner	Alexander Ospovat Rachel Laudan Martin Guntau
	German Romanticism	Nicolaas Rupke
	German Historicism	David Oldroyd
	James Hutton	Dennis Dean
19th century	Cuvier	Martin J. S. Rudwick
	Geological Society of London	Horace B. Woodward
	Lyell	Leonard Wilson Martin J. S. Rudwick

The studies noted in the latter half of Table 1 emphasize, on diverse grounds, the importance of developments near the end of the eighteenth or the beginning of the nineteenth centuries, the "heroic period of geology" famously named by Zittel.[24] Alexander Ospovat and other revisionist scholars have established the importance of Abraham Gottlob Werner, once dismissed as a regressive obstacle to the emergence of geology.[25] Since Ospovat, the most comprehensive attempt to reinterpret the origin of historical geology taking a constructive view of Werner into account is Rachel Laudan's argument for a largely Wernerian "adaptive radiation," from which geology developed in the early nineteenth century on the foundation

[24] Karl Alfred von Zittel, *History of Geology and Paleontology*, trans. Maria M. Ogilvie-Gordon (London, 1901; facsimile reprint, 1962), chapter 3 entitled "Third Period—The Heroic Age of Geology from 1790–1820."

of eighteenth-century mineralogy.[26] On the other hand, guided by Michel Foucault's schema positing a sharp epistemic break at the end of the eighteenth century, David Oldroyd and W. R. Albury see German historicism as providing the essential catalyst for a radically-novel form of historical thinking about the Earth. Similarly, in a pair of interesting studies Nicolaas A. Rupke argues for the role of German Romanticism and *Naturphilosophie*.[27]

In addition to continental trends, some scholars look toward developments in Britain circa 1800. Dennis Dean upholds the long-standing view of James Hutton as the father of modern geology; others take the stratigraphical concerns of the Geological Society of London as the standard against which previous approaches to the Earth should be measured.[28] Leonard Wilson continues to affirm Charles Lyell's self-presentation as the Newton of geology, the revolutionary creator of a new science.[29] Rupke explores the continuing significance

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25 Alexander M. Ospovat, "Abraham Gottlob Werner and His Influence on Mineralogy and Geology" (Ph.D. dissertation, University of Oklahoma, 1960); Abraham Gottlob Werner, *Short Classification and Description of the Various Rocks*, trans. Alexander M. Ospovat, with an introduction and notes (New York: Hafner Press, 1971); and Alexander M. Ospovat, "The Distortion of Werner in Lyell's Principles of Geology," *British Journal for the History of Science* 9 (1976): 190–198. Ospovat's constructive assessment of Werner has been widely corroborated; *e.g.* Martin Guntau, "Das Begreifen der Erdgeschichte und die Anfänge stratigraphischer Ideen in Deutschland," in *Cosmographica et Geographica,* ed. Bernhard Fritscher and Gerhard Brey (Münchener Universitätsschriften, München: Institut für Geschichte der Naturwissenschaften, 1994), 2: 97–113. See also the quotation from Anthony Hallam on page 265 below.

26 Rachel Laudan, *From Mineralogy to Geology: The Foundations of the Earth Sciences, 1660–1830* (Chicago: University of Chicago Press, 1987); hereafter, "Laudan, *From Mineralogy to Geology.*" Laudan's use of the ecological concept of "adaptive radiation" does not imply continuity in the strict sense of intrinsic extension of a narrowly-defined research core, but captures a sense of contingent continuity proceeding in a dialectic of historical descent with modification. In the words of one reputable reviewer, Laudan "correctly regards the work of Johannes [*sic*] Werner and his pupils as constituting the dynamic research tradition that generated historical geology, thus producing the transition, heralded by the title, 'from mineralogy to geology.'" Roy Porter, *Isis* 79(1988): 156. For a more critical review of Laudan's thesis, see Martin J. S. Rudwick, "The Emergence of a New Science," *Minerva* 28 (1990): 386–397. Laudan's arguments are discussed below; see "Amos Eaton, Fieldwork, and Wernerian Geognosy," beginning on page 695.

27 W. R. Albury and David R. Oldroyd, "From Renaissance Mineral Studies to Historical Geology, in the Light of Michel Foucault's *The Order of Things*," *British Journal for the History of Science*, 1977, 10: 187–215; David R. Oldroyd, "Historicism and the Rise of Historical Geology," *History of Science* 17 (1979): 191–213, 227–257; Nicolaas A. Rupke, "The Study of Fossils in the Romantic Philosophy of History and Nature," *History of Science* 21 (1983): 389–413, and Nicolaas A. Rupke, "'The End of History' in the Early Picturing of Geological Time," *History of Science* 36 (1998): 61–90. Oldroyd's article is discussed in "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354, and German developments are discussed in "Silberschlag, Caverns, and German Romanticism," beginning on page 687.

28 Dennis R. Dean, *James Hutton and the History of Geology* (Ithaca: Cornell University Press, 1992). On Hutton, see below, "Hutton and the Whig Interpretation of Geology," beginning on page 269. For an official account of the origin and early years of the Geological Society of London, see Horace B. Woodward, *The History of the Geological Society of London* (Burlington House, London: Geological Society, 1907).

of classical scholarship for the establishment and reception of geology at Oxford under William Buckland.[30] Combining French and British emphases, Martin J. S. Rudwick sees the work of Cuvier and Lyell together as establishing a truly geohistorical perspective.[31]

Mere summaries do not do justice to the interpretations briefly noted in Table 1; they and others which constitute a vast literature are rich in nuance and supported by detailed scholarship. Many will be considered at greater length below. At the outset, however, it is clear that any attempt to reconsider whether Theories of the Earth significantly shaped the development of historical sensibilities in the natural sciences (Roger's Relevance Thesis) is bedevilled by fundamental disagreements regarding both terms in the relation. That is, both "historical sensibility" and "Theory of the Earth" have been used in idiosyncratic and contradictory ways. Neither term is a transparent observers' category; both were mutable and contested actors' categories, and present discussions of their relationship remain deeply problematic.

§ 1-i. Interpretative Blinder #1: Idiosyncratic Definitions of Historical Sensibility

The diversity of views represented in Table 1 shows that no consensus exists regarding what might count as significant for the development of a genuinely historical sense of the Earth's past. Relying upon contrary definitions, one investigator may dismiss another's identi-

[29] Leonard G. Wilson, *Charles Lyell, the Years to 1841: The Revolution in Geology* (New Haven: Yale University Press, 1972), and Leonard G. Wilson, "Geology on the Eve of Charles Lyell's First Visit to America, 1841," *Proceedings of the American Philosophical Society* 124 (1980): 168–202. For a different view see Alberto Elena, "The Imaginary Lyellian Revolution," *Earth Sciences History* 7 (1988): 126–133. Lyell's views of Theories of the Earth are discussed below, "Lyell and Histories of Scientific Disciplines," beginning on page 280.

[30] Nicolaas Rupke, *The Great Chain of History: William Buckland and the English School of Geology* (1814–1849) (Oxford: Oxford University Press, 1983).

[31] For example, see Martin J. S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), especially p. xiii; "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 25–36, and "Lyell on Etna, and the Antiquity of the Earth," in *Toward a History of Geology*, ed. Cecil J. Schneer (Cambridge: MIT Press, 1969), 288–304.

fication of an example of historical thinking by saying "That's not truly historical." This lack of agreement results from a combination of the piecemeal development of historical thinking about the Earth and the piecemeal approach of the investigators. Given their partial views, differing emphases, limited scope, and sometimes contradictory conclusions, the studies suggest, when considered as a group, that the full story is complicated, that no monocausal account will suffice, and that no one temporal sensibility at one time in one place should be singled out for exclusive consideration. Whenever any of the arguments of the latter studies are taken up in isolation, associated with exclusive claims of a discrete, discontinuous origin of historical thinking about the Earth, then such conclusions are undermined by the arguments of the former studies, which must be taken into account in any satisfactory general discussion.

§ 1-ii. Interpretative Blinder #2: Idiosyncratic Definitions of Theories of the Earth

The studies summarized in Table 1 rarely focused on the textual tradition of Theories of the Earth. Despite the pioneering work of Jacques Roger and the echoes of a few other lonely voices, there has been little enthusiasm among historians of science for reassessing the possible significance of Theories of the Earth for the development of temporal sensibilities.[32] The lack of positive attention suggests that there is an insufficient appreciation of the diverse and contested character of Theories of the Earth. This oversight underlies Martin Rudwick's sweeping but unfortunately rather typical assessment that Theories of the Earth "proposed models or 'systems' for the causal development of the whole earth, but they were deeply ahistorical.… What all these 'systems' lacked was any significant element of the contingency that would

[32] Two noteworthy exceptions, besides Jacques Roger's "relevance thesis" and Kennard Bork's articles cited above are John C. Greene, *The Death of Adam: Evolution and Its Impact on Western Thought* (Ames, Iowa: Iowa State University Press, 1959); and more recently, Kenneth L. Taylor, "The Historical Rehabilitation of Theories of the Earth," *The Compass: Earth Science Journal of Sigma Gamma Epsilon* (Norman, OK) 69 (1992): 334–345.

have marked a truly geohistorical narrative."[33] Rudwick's interpretation implicitly denies that Theories of the Earth were a long-lived, international, multi-contextual tradition in which diverse views evolved in open contests with rival perspectives. Relying upon contrary definitions of Theories of the Earth, one historian may even agree with another's identification of a case of historical thinking yet still, following a definition like Rudwick's, utterly disregard its relevance to Theories of the Earth simply by stipulating, "That's not a Theory of the Earth." Rudwick himself provides an obvious example of such a disjunctive rhetorical maneuver by arguing that Cuvier was not a Theorist of the Earth, despite the fact that he has been regarded as precisely that by historical contemporaries and historians of geology.[34] Clearly, to reassess Roger's Relevance Thesis requires a fundamental re-examination of appropriate criteria for regarding texts as Theories of the Earth in order to avoid idiosyncratic delineations of the tradition.

The next two sections revisit in turn these twin problems of specifying what will count as a "historical sensibility" or a "Theory of the Earth." Once these two interpretative blinders are addressed, it will be shown that considerable illumination results from examining the interplay of various temporal sensibilities displayed in Theories of the Earth. With Theories of the Earth from Descartes to the generations of Cuvier and Lyell, natural philosophy and historical conceptions of nature combined in a matrix of yet underappreciated intellectual and cultural significance.

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[33] Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 27; Rudwick's argument is discussed at length below, beginning on page 346.

[34] On Rudwick's disjunctive rhetorical maneuver in defense of Cuvier see below, page 313. Another example is the way that British traditions of historiography long regarded Hutton's work as something other than a Theory of the Earth because he seemed so clearly correct; cf. "Hutton and the Whig Interpretation of Geology," beginning on page 269.

§ 2. What is a Historical Sensibility? A Taxonomy of Temporal Terms

In considering what should count as a historical sense of the Earth's past, many historians, like the historical actors themselves, cite a parallelism between cosmological conceptions of deep space and geological conceptions of deep time.[35] On this view, extension in time complements extension in space; the discovery of the immensity of the age of the Earth did for historical thinking in the geosciences what the alleged discovery of the vastness of the universe did for cosmology. That is, the postulate of vast amounts of time was a prerequisite for genuine historical thinking, and given an Earth of about 6,000 years duration the development of historical sensibilities was by definition inconceivable.[36]

More than duration alone seems to be involved, however, since from Aristotle to Philo classical advocates of an Earth that was eternal in duration also accepted the eternity of human habitation. Thus, a more nuanced version of this position might argue that a sense of an *ancient* Earth, neither young nor eternal, underlay the divergence of human history and geo-

[35] Perhaps the paradigm example is from Cuvier's Theory of the Earth: "We admire the power by which the human mind has measured the motions of globes which nature seemed to have concealed for ever from our view: Genius and science have burst the limits of space, and a few observations, explained by just reasoning, have unveiled the mechanism of the universe. Would it not also be glorious for man to burst the limits of time, and, by a few observations, to ascertain the history of this world, and the series of events which preceded the birth of the human race? Astronomers, no doubt, have advanced more rapidly than naturalists; and the present period, with respect to the theory of the earth, bears some resemblance to that in which some philosophers thought that the heavens were formed of polished stone, and that the moon was no larger than the Peloponnesus; but, after Anaxagoras, we have had our Copernicuses, and our Keplers, who pointed out the way to Newton; and why should not natural history also have one day its Newton?" Georges Cuvier, *Essay on the Theory of the Earth. With Mineralogical Notes, and an Account of Cuvier's Geological Discoveries, by Professor Jameson. With Additions, trans. Robert Kerr*, 3d ed. (Edinburgh: Printed for William Blackwood, Prince's Street; and Baldwin, Cradock, and Joy, Paternoster Row, London, 1817), 3–4. The felicitous phrase "deep time" was popularized in John McPhee, *Basin and Range* (New York: Farrar, Straus and Giroux, 1980,1981); reprinted as Part I of John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), winner of the 1999 Pulitzer Prize for non-fiction.

[36] One Theorist exclaimed: "The periods which to our narrow apprehension, and compared with our ephemeral existence, appear of incalculable duration, are in all probability but trifles in the calendar of Nature. It is Geology that, above all other sciences, makes us acquainted with this important, though humiliating fact. Every step we take in its pursuit forces us to make almost unlimited drafts upon antiquity. The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound which to the ear of the student of Nature seems continually echoed from every part of her works, is— Time!—Time!—Time!" George Poulett Scrope, *Memoir on the Geology of Central France; Including the Volcanic Formations of Auvergne, the Velay, and the Vivarais,* 2 vols. (London: Longman, Rees, Orme, Brown, and Green, 1827), 1: 165. This work was not a Theory of the Earth, but Scrope did write a Theory of the Earth which is discussed in "Scrope's Vulcanist Cosmogony," beginning on page 681.

history. On this view, *geohistorical* thinking is defined specifically as referring to the *prehuman* duration of the Earth:

> The evolutionary view of the natural world, which in its organic aspect we have come to associate so crucially with Darwin, needed far more than the mechanism of natural selection to lend it plausibility. It needed more than a Lyellian vision of vast *time*, within which natural selection could operate effectively. It needed equally, or perhaps even more, a concrete vision of an unimaginably lengthy *prehuman* history.[37]

The distinguished work of Martin J. S. Rudwick can be read as a life-long project devoted to the emergence, culminating in the work of Georges Cuvier and Charles Lyell, of this sense of a long and complex *prehuman geo*history.[38]

Some interpreters of the Scientific Revolution argue that the *reordering* of the universe, i.e., the breakdown of a hierarchical cosmos, was more significant than its mere enlargement in dimension.[39] In a similar manner, opposed to definitions of historical sensibility based simply upon temporal *duration* (analogous to mere spatial extension of the cosmos) are those which emphasize the *quality* of the past (analogous to different conceptions of how the cosmos was ordered). An immutable Aristotelian cosmos may provide an ideal companion for a nondirectionalist Earth, but a universe with suns, worlds and comets arising and passing away in continuing cycles or being prepared for ordained purposes seems to require something dif-

37 Rudwick, "Encounters with Adam, or at least the Hyenas: Nineteenth-Century Visual Representations of the Deep Past," p. 247; italics added. The anomaly that Lyell, an advocate of a steady-state Earth, nevertheless upheld a recent appearance of humans is considered by Michael J. Bartholomew, "Lyell and Evolution: An Account of Lyell's Response to the Prospect of an Evolutionary Ancestry for Man," *British Journal for the History of Science* 6 (1973): 261–303.

38 Rudwick describes his work in these terms in Martin J. S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), xiii; cf. the references cited in footnote 31 on page 19. Another important interpretation of the divergence of human history and geohistory is the work by Paolo Rossi cited in footnote 22 on page 16.

39 In terms of mere size, as Van Helden points out, Tycho's cosmology actually shrank the size of the entire cosmos by a third; Albert Van Helden, *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley* (Chicago: University of Chicago Press, 1985), 50. Lewis characterized the medieval universe as vertiginous rather than small; C. S. Lewis, *The Discarded Image: An Introduction to Medieval and Renaissance Literature* (Cambridge: Cambridge University Press, 1964), 98–99. Donahue argues that the change from solid to fluid heavens was more important than that from a geocentric to a heliocentric system; William H. Donahue, *The Dissolution of the Heavenly Spheres, 1595–1650* (New York: Arno Press, 1981). The so-called "Copernican principle," sometimes referred to as the principle of mediocrity (that our vantage point in the universe is typical rather than special), is more applicable to the spatially-homogenous cosmologies of Lucretius, Nicolaus of Cusa, or Descartes than to Copernicus.

ferent for the Earth's past. It was not so much that the Earth came to be regarded as a planet (for Copernican cosmology was compatible with stasis and cosmic incorruptibility[40]), but that in alternative cosmologies (e.g., Stoic, Epicurean, Cartesian, and chymical) planets and other cosmic bodies became regarded as impermanent.

Yet permanence and development or decay are not the only questions to consider. Was the Earth formed by a predictable series of events which might happen over again, a process of *genesis* that might produce similar results elsewhere in the universe? Or might the Earth have a unique *history*, its present state resulting from a unique succession of particular events? In a well-known article, David Oldroyd made these two options—genetic views and "historicism"—the central terms of his study of the development of geology.[41] Oldroyd clarified the definition of a truly historical view as attending to the *particularity* of *unique events* which must be *reconstructed* from remaining artifacts rather than predicted by general laws:

> For an historian approaches his task, not by appeal to general laws and 'boundary conditions,' but by rummaging in libraries and archives, selecting from the information there discovered.... It is the interest in the unique historical events, rather than general historical laws, that is the hallmark of the historian, and which characterizes the historicist attitude. Let us, therefore, distinguish between historical explanations, and those that require knowledge of a set of antecedent circumstances plus certain laws of change or development.[42]

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[40] One early Copernican who held to celestial incorruptibility, Thomas Digges, is discussed in Chapter 4.

[41] David R. Oldroyd, "Historicism and the Rise of Historical Geology," *History of Science* 17 (1979): 191-213, 227-257; hereafter Oldroyd, "Historicism."

[42] Oldroyd, "Historicism," 193. "I shall use the word 'historicism' to refer to a belief in the efficacy of offering explanations of the nature of things or phenomena by means of their history." Oldroyd, *"Historicism"*, 192. The usage of historicism, even with respect to German historicism, is plagued with much equivocation; cf. Georg G. Iggers, "Historicism: The History and Meaning of the Term," *Journal of the History of Ideas* 56 (1995): 129–152. Oldroyd's definition of genetic and historicist perspectives is fully in accord with Gould's usage of contingency in the quotation on page 6 (compare with my definition of contingency in footnote 1 on page 7), and with most other important discussions in the historiography and philosophy of geology (such as those byKitts, Roger, Simpson and others cited below). The terminological waters are considerably muddied, however, by Popper's use of "historicism" to refer to the genetic perspective, i.e., that historical inquiry provides causal knowledge of inexorable laws of development so that, for example, the future course of human history may be predicted; see Karl R. Popper, *The Poverty of Historicism* (New York: Ark Paperbacks, 1957,1960,1961). Despite his contradictory terminology, as we shall see, in arguing against "historicism" as he defines it, Popper (like Kitts) defends a perspective of the unique character of historical science that to a significant extent agrees with Oldroyd's meaning of historicism.

Clearly, this sense of *contingent history* is analytically distinct from the *geo*history as temporal duration just discussed. Contingency and prehuman duration are not coordinated variables; some writers who accepted a recent origin for the Earth nevertheless regarded the formation of the Earth as the result of an *irreversible series of successive events*, albeit proceeding at a rapid pace or having been concentrated during critical periods which punctuated longer times of relative equilibrium. Conceptualization of such a contingently formative sequence for the Earth, even if not requiring an extended geohistory, should not be dismissed as irrelevant to the development of historical sensibilities about the Earth's past. To the contrary, one might expect that the assumption of a short time scale, in contrast to eternalism, may have facilitated actors' perception of the difference of past worlds and the extent of terrestrial change.

TABLE 2. Taxonomy of Temporal Sensibilities, or Visions of the Earth's Past

Sensibility	Description	Examples
1. Non-Directionalist sensibility	**A. Steady-state** sensibility: uniformity of essential conditions through time	Aristotle, Seneca, Philo, Buridan, Kircher, Woodward, Maillet, Lamarck, Hutton, Lyell
	B. Cyclic sensibility: various sets of conditions recur over time	
2. Directionalist sensibility	**A. Genetic** sensibility: Formation through stages (usually predictable, repeatable or reversible) by means of general causes and regular laws. Synonyms for genetic views include developmental, genesis, epigenetic, eutaxiological, and ordained.	Descartes
	B. Historical sensibility; contingent history: reconstruction of an irreversible or unique sequence of particular events which might have turned out otherwise. A historical sensibility invokes events that are irreversible and/or not repeated and/or unpredictable.	Burnet, Steno, Pallas, Cuvier

This is not the place for extended philosophical analysis, but it is essential to clarify some of the important terms which frequently occur in historiographical discussions. Four diverse (but not discrete) temporal sensibilities are summarized in Table 2. The essential feature of nondirectionalist perspectives is stipulated as an Earth with more or less the same circumstances over time. George Gaylord Simpson distinguished two varieties of nondirectionalist models: first, "A *cyclic* steady state, with important, even catastrophic, changes in time but nevertheless with more or less regular return to essentially the same configurations (Hutton and followers)"; and second, "A *statistical* steady state, also with important changes but these so localized and so distributed as to maintain a more-or-less constant average in space and time (Lyell and followers)."[43] Simpson's cyclic and statistical models correspond to the descriptions of cyclic and steady-state views, respectively, in Table 2. However, it is worth noting that a single nondirectionalist Theory might be regarded as either steady-state or cyclic depending on which conditions are privileged over how wide or small a place and time.

In contrast to nondirectionalist sensibilities, directionalist views of Earth history envision an Earth with quite different circumstances over time. Simpson captured the key difference between directionalist and nondirectionalist views: "In any historical model, as opposed to a steady-state model in which maintenance of or return to a given state is postulated, there is a difference between any earlier and any later state in the system as a whole."[44] Simpson did not distinguish between genetic and historical versions of the directionalist model, and he contrasted the directionalist historical model to only the steady state model. However, his distinction may easily be applied to the cyclic model as well: on the one hand, *cyclic* elements within a *directionalist* framework recur in such a way that there is a difference between any earlier and any later round of the cycle. On the other hand, *linear* elements within a *cyclic* framework develop in such a way that the sequence may be repeated again in the same way in the next round of the cycle.

An extreme form of directionalism is described by Simpson as: "An irreversible sequence changing in a constant direction (Conybeare and others)."[45] The additional stipulation that

[43] George Gaylord Simpson, "Uniformitarianism: An Inquiry into Principle, Theory, and Method in Geohistory and Biohistory," reprinted in *Philosophy of Geohistory*, ed. Claude C. Albritton, Jr., Benchmark Papers in Geology (Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc., 1975), 279–280, italics added; hereafter Simpson, "Uniformitarianism."

[44] Simpson, "Uniformitarianism," 283.

change must occur "in a constant direction" superimposes aspects of progress, determinism, directedness and/or teleology (terms which may or may not be associated with any particular directionalist or nondirectionalist view; cf. Table 3). *Directed* views represent immanent forms of teleology or teleonomy, but I do not wish to engage the thicket of distinguishing between various teleological views here, so long as "directedness" in a teleological sense is not conflated with "directionalist."[46] Yet merely the first part of Simpson's definition, "an *irreversible* sequence," is sufficient to distinguish directionalist views from cyclic and steady-state models. Similarly, Hooykaas pointed to an irreversible sequence of unique events as the *sine qua non* of historical models.[47]

Within the directionalist sensibility the two options grade into one another just as did the two forms of nondirectionalist views. It is important to recognize that the distinction between genetic and historical forms of directionalism is not always discrete, but often depends upon subtler issues of epistemic aims and causal reasoning. The distinction blurs between genetic and historical explanations because causal reasoning is necessary in order even to identify or describe interesting events, as discussed below. However, not all directionalist sequences of events are *repeatable* or *predictable* from a knowledge of causes. Some events in all probability never will recur, some are contingent in that they might have been otherwise; knowledge of these must be reconstructed after the fact. In varying degrees or combinations these features (irreversibility, nonrepeatability, and unpredictability) characterize an *historical sensibility* and distinguish it from other temporal sensibilities. Such characteristics provide a basis for the common-sense distinction between *genetic* views of *predictable* development, such as embryology, and *historical* views of *reconstructed* sequences, such as a biography. The most

45 Simpson, "Uniformitarianism," 282.

46 For contrasting examples of an *historical undirected* view and a *genetic directed* view (both directionalist) see footnote 2 on page 7.

47 Reijer Hooykaas, "Catastrophism in Geology, Its Scientific Character in Relation to Actualism and Uniformitarianism," reprinted in *Philosophy of Geohistory*, ed. Claude C. Albritton, Jr., Benchmark Papers in Geology (Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc., 1975), 352; hereafter Hooykaas, "Catastrophism."

clearly genetic Theory of the Earth was that of Descartes, yet Conway Morris' view of the development of life is relatively genetic because it envisions a high degree of repeatability. In contrast, the Theory of the Earth of Cuvier, or Gould's view of the development of life on Earth, are both examples of historical models envisioning sequences of events that were neither repeatable nor predictable.

Considering these terms philosophically, the Theories of Thomas Burnet and Nicolaus Steno, although far more genetic than Cuvier's perspective, were based to a relatively significant degree on reconstruction of unique or unpredictable events that might have been otherwise. In Chapter 5 we explore the degree to which Burnet's Theory of the Earth (and controversies engendered by it) represented the emergence of an incipient perspective of directionalist historical change (as Jacques Roger suggested) in opposition to both Cartesian genetic development and Aristotle's framework of eternalistic meteorology. But these terms must always be used with careful qualifications and additional clarifications. A view such as Maillet's, for example, might be regarded as both directionalist (with respect to the present state of the Earth) and eternal (with respect to past and future states of the Earth as it passes through its cosmic cycles).[48] Similarly, a given Theory might be genetic with regard to some causes and historical with respect to other events, with terms of explanation shifting in emphasis between causes and events in various combinations and permutations.

[48] In terms of the above guidelines, it would seem that Maillet's Theory consisted of linear sequences occurring within a cyclic framework, but one might still argue that in this case the directionalist elements within the cyclic framework were most significant. Maillet's Theory is discussed in "Marginality and Mentalité," beginning on page 335.

TABLE 3. Temporal Sensibilities: Associated Terms

Other variables	Description	Examples
A. Duration	Eternal	Aristotle, Philo, Halley, Maillet, Toulmin
	Old (deep time, perhaps with a prehuman duration)	Buridan, Buffon, Deluc, Cuvier, Scrope
	Young	Steno, Woodward, Ray, Newton
B. Habitation	Earth always inhabited by human beings?	Aristotle, Philo
	Earth sometimes uninhabited by humans?	Cuvier, Lyell, Maillet
C. Pace	Saltational, episodic, "catastrophism": emphasizes significance of particular events (e.g. sudden uplift, impacts, collapses, major storms). (Saltational views are more amenable to periodization.)	Steno, Deluc, Hutton, Cuvier, Buffon
	Gradual, continuous rates: emphasizes significance of general processes (e.g., long-term erosion, gradual deposition, gradual uplift,)	Descartes, Buffon, Werner, Playfair, Lyell
D. Progress, teleology, directedness	Progressive: Often (but not always) genetic directionalist in cosmology, natural history, or the history of human civilizations. May be inherently purposive, determined, or contingently (externally) ordered. May be alchemical, providential, mechanical, evolutionary. (Linear models of life include the scala natura, great chain of being, or ladder of creation.)	Buffon, Lamarck, Cuvier, Herbert Spencer, Conway Morris
	Nonprogressive: Often (but not always) nondirectionalist. May be inherently accidental. Stasis, branching divergence. (Models of life include a mosaic, a map, a numerological scheme, or a bush.)	Hutton, Lyell, Darwin, Gould
F. Epistemic aims (knowledge of events, laws, causes, or some non-exclusive combination of the three)	**Actualism:** emphasis on agents and types of processes; **causal** knowledge (i.e., known causes); knowledge of the fact (quia); knowledge of the reason why (propter quid); demonstrative regress (regressus).	Descartes, Burnet
	Phenomenalism: emphasis on identifying regularities and establishing descriptive **laws** of known effects, without necessarily specifying familiar agents, mechanisms or causes. Also known as reducing to rule.	Newton, Werner
	Natural History: emphasis on establishing specific matters of fact, the occurrence of particular **events**, often as a prelude to investigating laws or causes.	Woodward

As suggested in Table 3, a number of other terms may be associated with any of the four temporal sensibilities. These additional characteristics are independent variables occurring with directionalist or nondirectionalist sensibilities in any combination. For example, to take an unlikely combination from the assorted variables for duration and habitation, it is possible for a young-Earth view such as Steno's to assign interesting events to the uninhabited, prehuman period of the first five "days" of the creation week. Unfortunately, there is no standardized nomenclature for discussing temporal sensibilities, and idiosyncratic combinations of these variables are sometimes referred to without discrimination.[49] Rappaport goes so far as to argue that historians should altogether eschew ahistorical labels such as catastrophism, uniformitarianism, and actualism.[50] Although desirable, a radical re-invention of nomenclature is not possible at this time, so the descriptions in Table 3 offer precise, minimal definitions of terms used in this dissertation which hopefully are stripped of rhetorical connotations and the most egregious historical baggage.

With a great deal of skepticism about the heuristic value of continuing to use the word *actualism*, I will refer to the epistemic aim of actualism as reasoning with knowledge of true causes. This reflects the usage of Hooykaas which has been widely adopted in English-language historiography and philosophy of geology: "The causes of geological changes in the past differ not in *kind*, though they may differ in *energy*, from those now in operation. This is

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[49] See, for example, Simpson's conflation of directionalism and directedness discussed above on page 26.

[50] "I have avoided terms all too familiar to modern readers: catastrophism, uniformitarianism, actualism, neptunism, vulcanism, and plutonism. These labels have their own history, and they may now possess connotations that impede historical analysis. If, for example, one calls Anton Lazzaro Moro a uniformitarian in principle but a catastrophist in practice, the words do not tell us that he assumed that nature works in uniform ways (a commonplace) and that a main natural mechanism is the volcanic eruption (a most uncommon assumption). Further confusion results if both Moro and Thomas Burnet are dubbed catastrophists, since Burnet used a single, worldwide cataclysm, the Flood, whereas Moro's eruptions were all local events occurring at various times. Catastrophism has also come to signify the use of inexplicable and even miraculous causes. Both Burnet and Moro, however, were resolutely naturalistic writers, opposed to the very method and viewpoint sometimes said to be typical of catastrophists. These limited examples should suggest why I have chosen to abandon misleading '-isms.' The sole exception is diluvialism; as used here... the word does not signify all theories incorporating the Flood, but only those in which the Flood played the most important role in shaping the earth's crust. Burnet was a diluvialist; Nicolaus Steno was not." Rappaport, *When Geologists were Historians*, 5.

actualism, though no uniformity of activity is assumed."[51] It is often remarked that on this definition, actualism differs from Lyellian "uniformitarianism" by allowing the intensity of geological causes to diminish over time.[52] Less frequently, perhaps, is it noticed that this now-common definition of actualism also implies that causal reasoning in some form is necessary to explain geological change, for to be a true cause, not differing "in kind" from known causes, a cause must be known to exist and be proven capable of producing the effects.[53]

Whether historically or philosophically considered the invocation of causes raises a multitude of problems. Critical ambiguities arise because there is more than one way to conceive of or to invoke a cause. In an historically-significant discussion, Aristotle presented in *Posterior Analytics* I.13 an analysis of two often-contrasted forms of causal reasoning: *quia,* reasoning from effects to a cause; and *propter quid*, demonstrating an effect from a known cause. In his famous example of a *quia* argument (Table 4), the major premise ("Planets do not twinkle") is an effect rather than the cause of the conclusion ("Planets are near"), so this syllogism is a demonstration of the "fact" (*quia*), not of the reason why. The minor premise ("What does not twinkle is near") is a universal statement obtained by some means, whether induction, analogy, or intuition.[54] This ambiguity raises the question as to what extent *quia* reasoning produces knowledge. The *quia* argument is an example of formally valid causal reasoning, but in practice it often seems uncertain because the minor premise raises the great problem of induction. The weakness of the middle step is illustrated in the right-hand column, for a

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[51] Hooykaas, "Catastrophism," 313; italics added.

[52] Rudwick defended Hooykaas' definition in an early, influential article, Martin J. S. Rudwick, "Uniformity and Progression: Reflections on the Structure of Geological Theory in the Age of Lyell," in *Perspectives in the History of Science and Technology*, ed. Duane H. D Roller (Norman: University of Oklahoma Press, 1971), 209–227. Another widely-read argument for distinguishing between actualism and uniformitarianism is Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge: Harvard University Press, 1987).

[53] For a relevant discussion of John Herschel's influential methodology of "verae causae" see Michael Ruse, *The Darwinian Revolution: Science Red in Tooth and Claw* (Chicago: University of Chicago Press, 1979), esp. 57ff.

[54] Against Baconian models of inductive reasoning, the role of analogy in geological reasoning was emphasized by John Herschel and others (see previous note). The importance of hypothesis and intuition in geological reasoning was emphasized against Herschel by William Whewell (cf. footnote 66 on page 38).

black swan is not a crow. In acknowledgment of this difficulty, the middle step may even be stated as a probability or qualified in other ways ("Black birds hereabouts are likely to be crows"; therefore "This bird is likely a crow"). It is not surprising, then, that in disputes over *quia* arguments the evidence for the minor premise is closely scrutinized and contested. The abundance of debates over the role of analogical reasoning and of polemical controversies over alleged mis-identifications of actual causes is therefore not surprising. In Chapter 5 we discuss how Thomas Burnet's Theory of the Earth displayed reasoning from effects to a cause and thereby focused attention on the methodological advantages of seeking actual rather than merely possible causes.

TABLE 4. Quia (to hoti) reasoning (from effects to a cause)

	Aristotle	Problem of Induction
Major premise (effect)	Planets do not twinkle	This bird is black
Minor premise	What does not twinkle is near	Black birds are crows
Conclusion (cause)	Therefore planets are near	Therefore this bird is a crow

TABLE 5. Propter Quid (to dioti) demonstration (from a cause to effects)

	Aristotle	Logical Positivists
Major premise (cause)	Planets are near	This bird is a crow
Minor premise	Near things do not twinkle	All crows are black
Conclusion (effect)	Therefore planets do not twinkle	Therefore this bird is black

Although equally valid, a *propter quid* argument, or demonstration of the "reason why" (Table 5), appears more desirable than a *quia* argument because it sidesteps the problem of induction. In twentieth-century terms, an argument *propter quid* has more to do with the justification of knowledge than with the context of discovery, for it begins with a known true cause ("Planets are near") stated as the major premise. A universal statement, usually an observed regularity, functions as the minor premise. The effect ("Planets do not twinkle") is explained when it is deduced from the cause. For Aristotle, therefore, explanations in *scientia* provide causal knowledge of that which necessarily follows from the premises and could not be otherwise. Twentieth-century logical positivists substitute empirical regularities or laws for Aristotelian definitions, but for them the same form of argument is necessary for a scientific explanation. In the language of logical positivists, the example of the crow illustrates a "covering law" model of scientific explanation. For Aristotle deductive, causal, *propter quid* knowledge was the aim of science, as is the covering law for logical positivists, yet in his *Meteorology* Aristotle often found it is necessary to settle for knowledge of the fact. Perhaps the most famous Theory of the Earth which features reasoning from causes to effects as the predominant epistemic aim is Descartes' *Principia philosophiae*. For Descartes, the Earth was a suitable object of causal knowledge, and therefore the Theory of the Earth could be a science or *scientia* in an Aristotelian sense.

As many seventeenth-century natural philosophers reflected upon Aristotelian methodology they came to argue that the only adequate method of causal reasoning is to combine the two forms in a process of analysis and synthesis. First, beginning with particular observations, one analyzes the true cause from its effects (*quia*). Second, in synthesis, one demonstrates new phenomena arising from the known cause (*propter quid*). In this two-fold "demonstrative regress" one proves facts from facts without jettisoning the epistemic aim of causal knowledge.[55] Clearly it is a mistake to characterize causal reasoning *in toto* as solely the attempt to deduce effects from causes.[56] In Chapter 5 we contrast Descartes' *propter quid* method of demonstration to Burnet's combination of *quia*, *propter quid* and *regressus* reasoning.

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[55] The most frequently-cited case of such methodological discussion is that of the demonstrative regress advocated by Jacopo Zabarella and other Paduan Aristotelians. For the present state of historiographical debate over their influence on Galileo see William A. Wallace, "Dialectics, Experiments, and Mathematics in Galileo," in *Scientific Controversies: Philosophical and Historical Perspectives*, ed. Peter Machamer, Marcello Pera and Aristides Baltas (Oxford: Oxford University Press, 2000), 100–124. For the equally interesting example of methodological reasoning in debates over William Harvey's Aristotelian anatomical investigations see Roger French, *William Harvey's Natural Philosophy* (Cambridge: Cambridge University Press, 1994), especially chapter 11. The late medieval state of methodological discussion is surveyed in Steven J. Livesey, *Theology and Science in the Fourteenth Century: Three Questions on the Unity and Subalternation of the Sciences from John of Reading's Commentary on the Sentences*, Studien und Texte zur Geistesgeschichte des Mittelalters, vol. 25 (Leiden: E. J. Brill, 1989). A magisterial survey of methodologies of analysis and synthesis is Alistair C. Crombie, *Styles of Scientific Thinking in the European Tradition*, 3 vols. (London: Duckworth, 1994). D'Alembert's prominent eighteenth-century expression of a similar methodology is discussed later in this chapter; see "System of the Earth," beginning on page 106.

Not every Theorist of the Earth insisted upon obtaining a demonstrative knowledge of causes. In contrast to actualistic causal reasoning, the more modest epistemic aim of *Phenomenalism* (also known as reducing to rule) emphasizes the identification of regularities and the establishment of descriptive laws which precisely summarize the relations between phenomena. To the extent that reified laws may be regarded as causes, the distinction blurs between actualism and phenomenalism. Like *quia* causal reasoning, a phenomenalist approach emphasizes known effects. Although phenomenalist descriptions may be undertaken as a prelude to *quia* or *regressus* reasoning, they stop short of invoking familiar agents and do not complete an inference to an actual cause. The programmatic phenomenalist may eschew knowledge of the essences of things in principle. The pragmatic phenomenalist does not cut off inquiry into causes but regards causal knowledge as unobtainable in a given matter. Therefore, as the old anti-catastrophist rhetoric feared, a phenomenalist approach is compatible with belief in occasional supernatural agency or regular preternatural effects. For example, phenomenalism is evident in Newton's defense of his noncausal mathematical law of gravitational attraction both when he programmatically suspected that it was the preternatural effect of the finger of God, and when he pragmatically cast about for possible causes in various alchemical, optical, and other investigations.[57] Phenomenalism likewise characterized not only the catastrophists (who in most cases neither invoked divine agency nor disdained the

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[56] Indeed, it is simplistic even to attribute a deductive model to Aristotle himself as in the previous paragraph. Recent scholarship has shown how distortions arise when Aristotle's methodology is described exclusively on the basis of his *Posterior Analytics* without considering its relation to the practice of something like a demonstrative regress in his biological works. Cf. Allan Gotthelf and James G. Lennox, *Philosophical Issues in Aristotle's Biology* (Cambridge: Cambridge University Press, 1987).

[57] A programmatic phenomenalism eschewing knowledge of the essences of things (consistent with both the voluntarist tradition of theology and the Anglican doctrine of the Eucharist) is manifest in Newton's "General Scholium" (1713); cf. Isaac Newton, *Mathematical Principles of Natural Philosophy*, trans. Andrew Motte (1729) and Florian Cajori, 2 vols. (Berkeley: University of California Press, 1934), 2: 543–547. For an introduction to recent literature on Newton's voluntarist theology and his investigations into the possible divine or natural causes of gravity see Betty Jo Teeter Dobbs, *The Janus Faces of Genius: The Role of Alchemy in Newton's Thought* (Cambridge: Cambridge University Press, 1991); and John Henry, "'Pray do not ascribe that notion to me': God and Newton's Gravity," in *The Books of Nature and Scripture: Recent Essays on Natural Philosophy, Theology, and Biblical Criticism in the Netherlands of Spinoza's Time and the British Isles of Newton's Time*, ed. James E. Force and Richard H. Popkin, Archives Internationales D'Histoire des Idées, no. 139 (Dordrecht: Kluwer Academic Publishers, 1994), 123–148. Cf. footnote 274 on page 151.

search for natural causes), but also the work of Woodward, Steno, Desmarest, and many eighteenth-century Newtonians.[58]

Finally, in contrast to actualism and phenomenalism, the epistemic aim of *natural history* is to establish particular matters of fact (*historia, quod sit, autopsia*), that is, that something actually happens to be the case. A natural historian establishes the occurrence of particular objects and events, making an inventory of the world and perhaps of historical events. As the relations between things or events are investigated, however, one often moves toward phenomenalism or some form of causal reasoning. For this reason natural history is undertaken as a prelude to investigating laws or causes, but it is also compatible with more modest epistemic aims. However, it is easy to be led astray by the fact that *historia* strictly refers to descriptive knowledge in contrast to causal understanding.[59] As one textbook surmised:

> Originally geology was essentially descriptive, a branch of natural history. But by the middle of the twentieth century, it had developed into a full-fledged physical science making liberal use of chemistry, physics and mathematics and in turn contributing to their growth.[60]

To refer to geology before the twentieth-century as merely descriptive is completely untenable, as Kitts explains:

> But geological observation and geological generalization take place almost wholly within a complex system of general preconceptions—a system so complex that we cannot hope with any reasonable effort to identify all of its components.... In a very significant sense, then, geologists do not approach their subject matter with an open mind. They do not give equal weight to what their senses tell them. They take into account only that which is already imbued with theoretical signifi-

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58 Newton was not the only model for phenomenalism; Steno's anti-Cartesian methodology was indebted to Gassendi (see "Steno's Tuscan Autopsy," beginning on page 562). For the instructive example of Desmarest's phenomenalism, inspired by Newton, see Kenneth L. Taylor, "La Genèse d'un Naturaliste: Desmarest, La Lecture et la Nature," in *De la Géologie à Son Histoire*, ed. Gabriel Gohau (Paris: Comité des Travaux Historiques et Scientifiques, 1997), 66–67. Woodward's Theory is described in "Mosaic Theories: Fossil Emplacement by Diluvial Dissolution," beginning on page 641.

59 Nor did "history" in the seventeenth and eighteenth centuries refer to historical understanding in a temporal sense.

60 L. D. Leet and S. Judson, *Physical Geology* (New York: Prentice Hall, 1954), as quoted in David Burlingame Kitts, *The Structure of Geology* (Dallas: SMU Press, 1997), 57.

> cance, and they do not formulate principles and generalizations by an inductive enumeration of observations.[61]

Inquiries in both Theories of the Earth and nineteenth-century geology were undertaken as exercises in natural history which made liberal use of available theoretical knowledge. The contrast between natural history and other epistemic aims therefore is not that natural historians avoid invoking causes or theoretical knowledge, but rather one of emphasis: what they do with the causes they employ. Merely to describe complex phenomena or to identify interesting events requires the naturalist to employ theoretical assumptions about possible and relevant causes. Naturalists were not stamp collectors who wished they could be physicists. To oversimplify for heuristic purposes, natural history may be regarded as invoking causal knowledge only in order to describe singular things or events; natural philosophy emphasizes how theoretical knowledge relates things and events in a causal order.

A link between natural history and historical explanation thus lies in their shared emphasis on particular events, but what of rare events for which theoretical understanding is insufficient or causal knowledge is unobtainable? Can there be a science of rare events, such as reports of UFOs, sightings of the Loch Ness monster, cosmic singularities or unexpected geological catastrophes?[62] Is it possible to subject rare events to scientific explanation? Questions like these are raised by the general problem of understanding how natural history was transformed into the history of nature. Because historical scientists today realize that "nothing of historical interest will be discovered as a rigorous deductive consequence of theory,"[63] they perhaps therefore expect little of significance to have been discovered by so-called "theorists" of the Earth. Yet we have seen that deductive, *propter quid* knowledge was only one of several

[61] Kitts, *Structure of Geology*, xviiii-xix.

[62] An excellent discussion of difficulties facing any science of rare events is Henry H. Bauer, *The Enigma of Loch Ness: Making Sense of a Mystery* (Urbana: University of Illinois Press, 1988). Difficulties posed by the rarities of UFOs are encountered in Jim Schnabel, *Round in Circles: Poltergeists, Pranksters, and the Secret History of Cropwatchers* (Amherst, New York: Prometheus Books, 1994).

[63] Kitts, *Structure of Geology*, 99.

possible epistemic aims of Theories of the Earth. Given the entangled gradations between actualism, phenomenalism, and natural history what, then, are the possible epistemic aims of *historical sciences*? In what sense might a story *explain*?

Given a definition of directionalism as envisioning an irreversible sequence of unique events, it is sometimes said that historical sciences deal with unique events (or at least rare ones), whereas other sciences deal with repeatable events. However, in a strict sense all events are unique, both those which are presently observable and those which are past. More precisely, we may say that interesting historical events are always too complex to be predictable. Yet in the very act of identifying a complex event, and still more of describing it, an event or series of events becomes seen as one of a kind, as possessing general properties exemplifying a general category, although in a unique configuration. For this reason, as noted above, events are recognized with the aid of theories that help us to interpret them. In this way the difference between historical and genetic sensibilities seems mainly one of emphasis. As Popper noted, "historical sciences take all kinds of universal laws for granted and are mainly interested in finding and testing singular statements."[64] The upshot is that we cannot learn of new causes from history if we are not already prepared to discern them at work there. A complex event such as an overthrust, or a series of depositional events, are theoretically identified (and even altered if need be), in order to conform to theoretical knowledge: "It is thus not a simple matter of determining which theory best accounts for the same event. The events which we regard as significant have already been 'filled out' or 'enriched' in terms of some theory."[65] In other words, meta-theoretical conceptions of *possible* causes are applied or imposed upon the records of the past, not vice versa, as if unknown causes could simply be read from the rocks.[66]

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64 Popper, *Poverty of Historicism*, 144.

65 David Burlingame Kitts, "Paleontology and Evolutionary Theory," *Evolution* 28 (1974): 468. As an example, Kitts discusses Steno's laws of superposition: "For centuries geologists have been telling their students that the law of superposition is self-evident and have thereby done Steno, who formulated the law, and themselves, who use it every day, a great injustice. It is self-evident, I suppose, that when objects are stacked up one after the other, the objects lower in the stack were put down earlier. It is not self-evident, however, that sedimentary rocks may be considered as members of the class of things that are stacked up one after the other. The justification for this assumption rests, not on its self-evident truth, but on an elaborate *theory* of sedimentary rocks which in turn rests upon physical and chemical theory." Kitts, *Structure of Geology*, 113; cf. footnote 286 on page 572.

It follows that when beliefs regarding possible causes change, earlier inferences become regarded as speculation carried out in defiance of the actualistic attempt to discern true causes. One typical example is the Neptunist conception of a gradually-diminishing primeval ocean. It shows how the reconstruction of an historical event may serve to establish the initial conditions for a theoretical, genetic account, or may be pursued as an end in its own right. For the Neptunist ocean could function for chemical mineralogists in the laboratory as a true cause, the basis of a genetic scheme in a theoretical science. Yet to geognosts in the field who inferred its action on the basis of recurring patterns in the sequence of strata, the primeval ocean was an empirical inference in a historical science.[67] Once knowledge becomes obsolete, the outdated causes once invoked become patently obvious flaws in the earlier web of explanation. Thus when the Neptunist ocean was no longer accepted, the Huttonian Daniel Mackintosh referred to the outdated inference that granite is the oldest kind of rock as an "imaginary conjecture."[68] Theoretical knowledge latent in any descriptive endeavor sticks out like a sore thumb whenever the cause once taken to be relevant changes.

The recognition of the necessary background role of causal precommitments in historical explanation underlies the argument of logical positivists such as Carl Hempel that there is no tenable distinction between historical and nonhistorical sciences.[69] For Hempel, an explana-

66 This difficulty lay behind Whewell's rejection of Herschel's *verae causae* methodology. Whewell complained that analogical (actualistic) reasoning "forbids us to look for a cause, except among the causes with which we are already familiar. But if we follow this rule, how shall we ever become acquainted with any new cause?" William Whewell, Philosophy of the Inductive Sciences, Founded upon Their History, 2 vols. (London: John W. Parker, 1840), 2: 442-443; quoted in Ruse, *Darwinian Revolution*, 58. Cf. Popper, *Poverty of Historicism*, 111; Kitts, *Structure of Geology*, passim.

67 This argument is elaborated below; cf. "Geognosy and the Wernerian Adaptive Radiation," beginning on page 116. The two sensibilities, genetic and historical, regarding the Neptunist primal ocean are analogous to the contrast between continental drift and plate tectonics described by Kitts. Kitts writes that continental drift "makes no assertions about an untimebound and unspacebound natural order, but about conditions prevailing at particular times and places. It is, in short, historical rather than theoretical." He concludes: "The hypothesis of continental drift does not serve the function of covering generalization in this explanation, but of initial and boundary conditions." Kitts, *Structure of Geology*, 118, 120. In contrast, Kitts describes plate tectonics as theoretical rather than historical in its appropriation of physical theory(pp. 123-124).

68 Daniel Mackintosh, *A Key to Geology: Being a Cursory View of the Present State of Discovery regarding the Structure and Revolutions of the Earth* (Edinburgh: John Anderson; Glasgow: John MacLeod; London: Simpkin, Marshall & Co., 1839), 12.

69 Carl G. Hempel, "The Function of General Laws in History," *Journal of Philosophy* 39 (1942): 35–48. Hempel argues that (p. 45): "in history as anywhere else in empirical science, the explanation of a phenomenon consists in subsuming it under general empirical laws." He concludes (p. 48): "the separation of 'pure description' and 'hypothetical generalization and theory-construction' in empirical science is unwarranted; in the building of scientific knowledge the two are inseparably linked."

tion applied to the past is formally identical to a prediction applied to the future, and all historical explanations are merely the application of general theories to historical information—that is, they are *pseudohistorical* rather than possessing a unique, *historical* methodology. Yet Hempel's argument applies only to genetic schemes where questions about events are settled on the basis of theoretical considerations, as in Descartes' account of planetary formation. By thus reducing historical explanation to pseudohistorical form, Hempel believes he has established the methodological unity of science along the covering law model of "all crows are black."

Like Hempel, Karl Popper holds that historical explanation may be scientific, despite adhering to a hypothetico-deductive model of scientific knowledge in contrast to Hempel's covering law model. Nevertheless, Popper argues that the historical sciences are distinctive because they seek to hypothesize and test statements about particular events. In contrast to the historical sciences, Popper explains, theoretical science seeks to hypothesize and test statements about theories, generalizations, or universals.[70] The difference for Popper is a difference in emphasis, not in the logical structure of theory. Kitts endorses Popper's distinction and applies it to the structure of geology:

> The difference between the theoretical sciences and the historical sciences does not lie in the theories which are invoked or in the inferential use to which these theories are put. It lies rather in what those engaged in the two kinds of sciences see as their goal. For historical scientists, singular descriptive statements are the end and theories are a means to that end. For theoretical scientists, theories are the end and singular descriptive statements are a means to that end.[71]

Popper's distinction is sweeping—it implies that even detectives, physicians, engineers, and biblical interpreters can act as historians—but it does justice to a common-sense distinction between two different aims or ends: the historical scientist, like the natural historian, moves from theories to events, and the theoretical scientist moves from events to theories.[72]

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[70] See Karl R. Popper, *The Poverty of Historicism* (New York: Ark Paperbacks, 1957,1960,1961), esp. 143–147. Popper writes (143–144) that "history is characterized by its interest in actual, singular, or specific events, rather than in laws or generalizations. This view is perfectly compatible with the analysis of scientific method, and especially of causal explanation, given in the preceding sections. The situation is simply this: while the theoretical sciences are mainly interested in finding and testing universal laws, the historical sciences take all kinds of universal laws for granted and are mainly interested in finding and testing singular statements."

[71] Kitts, *Structure of Geology*, xvi.

To a theoretical scientist, according to the Popperian distinction, accidental flux is either unintelligible, or the particularities of history are uninteresting. Unique events have value only insofar as they provide opportunities to discern the universal within the particular. Once the unchanging essence of an event is abstracted only meaningless idiosyncrasies remain, and such accidents are for the most part ignored as not worthy of study. Because on this view past events differ only accidentally from the present, Kitts points out that history becomes uninteresting as a survey of meaningless idiosyncrasies. As Seneca wrote, in a frequently-quoted line: "We are now seeking the natural and usual cause, not the rare and accidental."[73] Despite these emphases, however, because a phenomenalist's identification of regularities does not require him to infer that patterns or sequences of events were causally related, a historical rather than merely genetic sensibility might be nurtured in some enterprises of theoretical science. Historical sciences are compatible with natural history, phenomenalism, and with *quia* or *regressus* forms of actualism, because they embrace a non-deductive epistemic aim: "Theory permits the geologists to decide what is possible and what is not. But history goes beyond a consideration of what is possible to a consideration of 'what actually happened.'"[74]

In contrast, to a historical scientist who emphasizes descriptive statements (according to Popperian terminology), rare events—if substantiated by reliable testimony—are not merely accidents in an Aristotelian sense. Of course, rare events (including marvels, monsters, and wonders of nature) are empirically indistinguishable from *mirabilia*, or miracles. Yet instead of being regarded as occurring by chance, and therefore unintelligible, they may be regarded as signs or identified as anomalies. That is, marvels and wonders may be singled out as rare and unusual against the background of a regular and ordinary natural order, which constrains expectations of normality. But more than that, there may develop a sense that rare events may be as important as regularities, that the occurrence of, say, six fingers results from combinations of ordinary causes and not from chance.[75] In such a sensibility lies a germ of historical

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[72] This suggestion that the historical scientist emphasizes events rather than theories is one of the themes explicit in Oldroyd's definition of historicism (page 24).

[73] Seneca, *Natural Questions* II, 55.3; Lucius Annaeus Seneca, *Naturales Quaestiones*, trans. Thomas H. Corcoran, vol. 1, 2 vols., Loeb Classical Library, no. 450 (Cambridge: Harvard University Press; London: Heinemann, 1971), 186–187.

[74] Kitts, *Structure of Geology*, 126.

perspective, for being distinct from events which are expected or predictable, marvels must be carefully substantiated empirically or reconstructed historically.[76] That is, rare *events* may be temporally ordered without being explained as predictable by deduction from general causes.

The Popperian expectation that causal explanation is necessary for scientific knowledge is consistent with the actualist model for historical science where the difference between historical and genetic sensibilities is one of emphasis. Yet many writers note that interesting historical events are not predictable from causes, but result from a combination of a myriad of (perhaps unknown) causes.[77] To the degree that phenomenalism is distinguished from actualism (or the degree to which an actor's epistemic aim falls short of causal knowledge), a diminished sense of ontological necessity accords with a mode of historical explanation of non-necessary events which might have been otherwise. In summary, then, although historical and genetic sensibilities grade into one another on several levels, nevertheless we may say that an historical sensibility, rather than a genetic temporal sensibility, exists when any of the following criteria apply:

[75] In medieval commentaries on Aristotle's *Physics*, the case of a six-fingered person was a favorite example of a chance event. Fourteenth-century natural philosophers such as William Ockham and Jean Buridan argued, as had Augustine and Boethius before them, that causality was not violated in the production of apparently chance events, emphasizing a concurrence of causal chains in a completely determined causal nexus with a concomitant de-emphasis on the need for final causes within nature. Within a complete nexus of efficient causes, final causes become redundant, quite contrary to the Aristotelian view in which efficient causes, working alone, produce merely chance outcomes. Teleological aspects were thereby transfered from nature itself to voluntary agents extrinsic or transcendent to the natural order, lying remotely at the origin of each chain of efficient causes (e.g., God, angels, and human souls). With an emphasis on divine omnipotence, then, natural teleology became transcendent, with the end of all creatures located in the God from whom they received their being, in contrast to the immanent natural teleology of Aristotle, which allotted forms and ends to essences within nature, a perspective which negated the possibility of regarding rare events as possible objects of knowledge. Cf. Anneliese Maier, *On the Threshold of Exact Science: Selected Writings of Anneliese Maier on Late Medieval Natural Philosophy*, trans. Steven D. Sargent (Philadelphia: University of Pennsylvania Press, 1982), 164–166.

[76] On the early modern pre-occupation with natural marvels see Lorraine J. Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1988).

[77] These many writers include Popper and Kitts. Popper concedes that the aim of historical inquiry is not always one of explanation in a strict sense. For Popper, historical *explanations* must be causal to be scientific, although the emphasis of historical inquiry is not upon general causes *per se*. Rather, historians tend to emphasize *descriptions* of singular events rather than general explanations. Popper, *Poverty of Historicism*, 147. Similarly, Kitts notes that "there is more here than just some new instances of old familiar kinds of events. These events are ordered with respect to one another in space and time, and furthermore this ordering is not based wholly upon presuppositions of causal relationship.... The ability of geologists to discover unexpected patterns among the events of the past is particularly significant because they claim to have discovered recurrent patterns of events which they designate by generic names." *Structure of Geology*, 87. I make a similar argument with respect to Wernerian geognosy in "Wernerian Historical Geology redivivus," beginning on page 705.

- past events are *temporally ordered* without specifying causal relationships (i.e., how they might have been predicted); or
- past events are *reconstructed* on the basis of artifacts and empirical evidence; or
- an *irreversible*, unidirectional, unique series of complex events is deployed as an explanation for present circumstances.

The first two criteria emphasize the contingency of past events, that they might have been otherwise.[78] The third emphasizes their explanatory role, that they become intelligible in retrospect when reconstructed from their effects. All three are distinct from genetic explanations understood as the pseudohistorical, covering-law form of explanation advocated by Hempel. None of the three conforms to a *propter quid* type of causal explanation. All of them are immediately compatible with the epistemic aims of phenomenalism and/or natural history. Any of them could produce knowledge useful for actualistic causal reasoning.

Therefore the intuitive distinction between genetic and historical explanations (the two forms of directionalist sensibilities) is defensible, however blurred by changing emphases or differing epistemic aims. However, at some point in any attempt to define various temporal sensibilities (such as the present section) the making of further logical distinctions seems of diminishing historiographical importance, whatever the interest of these matters to philosophers.[79] What are the essential criteria for historical perspectives of the Earth? What will count as a historical view as distinguished from other temporal sensibilities? These are contested issues, and the present aim is not so much to insist upon precise formulations as to attend to the contest. The approach in subsequent pages is therefore necessarily eclectic,

[78] I define contingent events as those which might have been otherwise in footnote 1 on page 7.

[79] The best discussion of the character of geology as a historical science is Kitts, to whom I am greatly indebted; David Burlingame Kitts, *The Structure of Geology* (Dallas: SMU Press, 1997). Space does not permit us to mention other issues regarding the philosophy of time. However, the failure to take note of such philosophical debates here does not imply that they are either useless or irrelevant, for many were addressed by modern geologists as well as early modern natural philosophers. For example, in his novel *The Dechronization of Sam Magruder* George Gaylord Simpson's protagonist verified a quantum view of time which refuted the existence of a temporal continuum. George Gaylord Simpson, *The Dechronization of Sam Magruder*, ed. Joan Simpson Burns (New York: St. Martin's Press, 1996). For a survey of views of time and chronometry (not necessarily related to views of *history*) see G. J. Whitrow, *Time in History: Views of Time from Prehistory to the Present Day* (Oxford: Oxford University Press, 1988); for a survey of philosophical issues see Robin Le Poidevin and Murray MacBeath, eds., *The Philosophy of Time*, Oxford Readings in Philosophy (Oxford: Oxford University Press, 1993).

admitting that representatives of all of the available alternatives participated in a tradition of debate which witnessed the development of contingently historical sensibilities regarding the Earth. To define a timeless essence of an historical conception of nature is not a prerequisite for reconstructing the dialectical development of historical sensibilities resulting from debates between proponents of all of these views.[80]

[80] Attempts to define a *timeless* essence of an *historical* conception of nature, ironically, approach the oxymoronic. "Historical sensibility" is employed throughout this dissertation to refer to one of the four "temporal sensibilities" outlined in Table 2, without essentially specifying any additional variables such as those listed in Table 3. In defense of this broad definition, I suggest that an *historical* definition of an historical conception of nature should adopt an historical methodology, considering a philosophically less precise and historically more eclectic notion of what historical thinking about the Earth may have entailed. This is only to say that a historical sensibility should guide investigations of the development of historical sensibilities.

§ 3. What were Theories of the Earth? A Clarification of Terms

We turn now to some of the issues that underlie attempts to identify Theories of the Earth and to sketch some contours of the tradition. Again, brief clarifications of terminology are requisite:

First, I capitalize *Earth* to designate the entire globe as a body, just as names of planets are capitalized. On the other hand, *earth* may refer to dry land (such as emerged from the ocean on the third day of the creation account in Genesis); a particular region (such as Modena, the delta of the Nile, or the horizon as viewed from Ararat); an elemental principle (Aristotle); or a category of mineralogical substance (as contrasted with stones, salts, metals, or minerals, etc.). The chemical research of René Antoine Ferchault de Réaumur (1683–1757) was significant for Theories of the Earth. However, his "De la nature de la terre en général," was not a Theory of the Earth but a chemical study of mineralogical earths (as the complete title indicates).[81]

Second, more importantly, I capitalize *Theories of the Earth* to refer to texts in a historically-constituted tradition. Any mere conceptual scheme or *theory* about the Earth, considered in the abstract, is not capitalized, since the tradition is better delineated by criteria of historical appropriation, interaction, and textual tradition rather than *defined* by an alleged set of key concepts or essential methodologies. Given the second interpretative blinder, neither the distinction nor the preference just stated are necessarily obvious; important ramifications are considered in the remainder of this section, beginning with four clarifications regarding Theories and (1) Disciplines, (2) Texts, (3) Facts, and (4) Practices.

[81] Typographical conventions noted here apply only to my own writing; of course, capitalization of these words within quoted texts has not been altered. R. A. F. de Réaumur, "De la nature de la terre en général, et du caractere des differentes espèces de terres," *Memoires de Mathematique et de physique* (1730, published 1732): 243-283; cf. "Sur la nature de la terre en general, et sur ses caracteres," *Histoire de l'Académie Royale des Sciences* (1730): 23-32. For a convenient overview of the development of mineralogical classifications, see Laudan, *From Mineralogy to Geology,* Table 1 (pp. 23–25), and Charles Spencer St. Clair, "The Classification of Minerals: Some Representative Mineral Systems from Agricola to Werner" (Ph.D. dissertation, University of Oklahoma, 1965).

§ 3-i. Theories and Disciplines

What was the conceptual scope of Theories of the Earth? Did the "Theory of the Earth" comprise a distinct discipline or field of inquiry with a defining set of essential concepts, or was it a multi-contextual discourse? Some Theorists, followed by many historians, have defended the conception of Theories of the Earth as a distinct discipline organized around one or a few essential defining concepts. However, contradictory answers have been given regarding just what that essential defining concept might be. As we shall see, many nineteenth-century writers differentiated their emerging technical traditions from Theories of the Earth by defining the latter as restricted to the remote, original formation of the globe.[82] Yet Hutton defined "the Theory of the Earth" as research devoted to the single question of how nature perpetuates a habitable world, thus ruling out of consideration Buffon's cosmogenesis with its long, inhospitable epochs. Disregarding Hutton but with an eye on Buffon, Lyell stipulated that Theories of the Earth were characterized by their invocation of cosmogonical considerations. In a different but equally misleading characterization, Cuvier stated that all inquirers prior to himself had devoted themselves to explaining all of the Earth's history by reference to only two events, the Creation and Flood.[83] Examples of contradictory conceptual definitions are easily multiplied, yet these make clear that Theories of the Earth were marked by a profound conceptual disunity, were contested on many levels, and were a broader tradition than many of the participants wished to acknowledge. If, then, Theories of the Earth are more properly characterized as a multi-contextual discourse, then questions arise regarding how evidence from many recognized fields was brought to bear on overlapping questions of comprehensive scope.

[82] Cf. Humboldt's defense of the technical tradition of geognosy in footnote 189 on page 721, and Mackintosh's defense of the technical tradition of geology on page 729.

[83] Georges Cuvier, "The Revolutions of the Globe," in *Georges Cuvier, Fossil Bones, and Geological Catastrophes*, trans. Martin J. S. Rudwick (Chicago: University of Chicago Press, 1997), 199.

Whether geology, geophysics, meteorology and other Earth and planetary sciences are unified today remains problematic, but any basis for a unified science of the Earth was much less clear in the seventeenth and eighteenth centuries. At first glance, Theories of the Earth might seem to be defined as the science which has the Earth as its object of study. Yet the superiority of defining a science not by its object of study but by the aspects of the object it studies or by its manner of proceeding is illustrated by the medieval maxim that cosmology and astronomy each prove the sphericity of the Earth; the former by arguments from physics such as gravity, the latter by arguments from celestial phenomena such as eclipses and the altitude of the north star at different latitudes.[84] But which methods can define a field of inquiry based on a single object, when that object of study has multifarious aspects? Which aspects of the Earth should be privileged and granted methodological significance? What formal characteristics of the Earth most adequately comprehend its diverse properties? May the Earth even be conceived as a unitary object, on which basis one might pursue a coherent *scientia* of the Earth? That is, does the Earth present (1) a simple aggregate of features, like a heap of stones, to be described only by a heap of aggregated disciplines; (2) an object of inherent unity *per se,* like a vital organism, with demonstrable causes; or (3) a composite unity, even an accidental ordering of diverse aspects, perhaps like a house containing disparate objects in a nevertheless functional manner?[85] And to what extent is its order, however conceived, the result of past events, so that explanation in the form of historical reconstructions might seem plausible?[86]

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[84] See, for example, Thomas Aquinas, *Summa Theologica*, I.1, and footnote 85 on page 406.

[85] Such questions arose from longstanding debates about the unity of science and the relations of disciplines, based upon Aristotle's remarks in *Posterior Analytics* I.28, 87a–87b. For a concise survey of medieval developments see the introductory essay in Steven J. Livesey, *Theology and Science in the Fourteenth Century: Three Questions on the Unity and Subalternation of the Sciences from John of Reading's Commentary on the Sentences*, Studien und Texte zur Geistesgeschichte des Mittelalters, vol. 25 (Leiden: E. J. Brill, 1989); and John P. Doyle, "Suárez on the Unity of a Scientific Habit," *American Catholic Philosophical Quarterly* 65 (1991): 331, 333.

[86] Analogous problems arose for cosmology, given the lack of repeatability of the universe as a whole. See, for an interesting twentieth-century example, Helge Kragh, *Cosmology and Controversy: The Historical Development of Two Theories of the Universe* (Princeton: Princeton University Press, 1996), 241–249.

For early modern writers, the Earth was an individual *sui generis,* either considered as the unique center of a geocentric cosmos or as the only planet of which humans enjoyed first-hand knowledge. This particularity made the Earth a prime object of study despite the lack of consensus for how to go about it. It is not surprising that, prior to Theories of the Earth, knowledge of the Earth was parsed among a host of disciplines and discourses. Before the rise to prominence of Theories of the Earth in the seventeenth century a host of sciences treated the Earth according to one aspect or another, using methods more or less appropriate to their particular questions. However, few of these provided a unified framework capable of comprehending all of the traditional sciences and of keeping pace with rapidly proliferating discoveries while at the same time privileging historical explanations of the Earth. However, three medieval and Renaissance discourses that in different ways were comprehensive, multi-contextual inquiries about the Earth were meteorology, alchemy, and the long-standing tradition of producing voluminous commentaries on the first chapter of Genesis (known as the hexameron, or creation week). These and other discourses were synthesized in early Theories of the Earth and are discussed below.[87]

On the 200th anniversary of James Hutton's Theory of the Earth, a self-styled modern theorist of the Earth listed some of the disciplines now required for historical explanations of the Earth: "The questions of origin, composition and evolution of the Earth require input from astronomy, cosmochemistry, meteoritics, planetology, geology, petrology, mineralogy, crystallography, materials science and seismology, at a minimum." Anderson continued:

> The maturing of the Earth sciences has led to a fragmentation into subdisciplines which speak imperfectly to one another.… In spite of the fact that there is only one Earth, there are probably more theories of the earth than there are of astronomy, particle physics or cell biology where there are uncountable samples of each object.[88]

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[87] For a brief overview of comparable traditions in Islamic natural philosophy see Seyyed Hossein Nasr, *Science and Civilization in Islam* (Cambridge: Harvard University Press; reprinted New York: Barnes and Noble, 1968), esp. chapter 3, "Cosmology, Cosmography, Geography, and Natural History."

[88] Don L. Anderson, *Theory of the Earth* (Boston: Blackwell Scientific Publications, 1989), Preface, p. xi.

The multiplicity of Theories of the Earth in part reflects the multiplicity of discourses and disciplines with potential contributions to the natural knowledge of the Earth. Despite their multiplicity, and in part because of the variety of discourses they represented, seventeenth- and eighteenth-century Theories of the Earth provided an overarching discourse in which scholars and writers from diverse intellectual and institutional contexts could "speak to one another," or at least contend with one another before the open court of the reading public.

The variety of scholarly contexts appropriated by diverse Theories of the Earth was as immense as the globe itself: traditions of cosmology, geography, providential theology, mineralogy, and even the interpretation of ancient mythology, all played significant roles in particular Theories of the Earth, with or without traditions of biblical commentary. From traditional discourses Theorists of the Earth appropriated many commonplace topics, including questions regarding volcanos, earthquakes, the separation of dry land from the sea, the water cycle, the Earth's interior core, the nature and origin of mountains, rock formations, metals, mineral veins, and fossils. Different topics were emphasized in different Theories of the Earth, which were a diverse and heterogeneous group that in no way constituted a conceptually-unified research program or single discipline.

Thus the constitution of Theories of the Earth as a textual tradition created an object-oriented discourse (unified by its object of study) mediating between various configurations of different aspect-oriented disciplines (distinguished by their techniques or methodologies), including the pre-modern disciplines which Theories appropriated and a reconfigured, nineteenth-century set of geoscience and planetary science disciplines that were well-suited to investigate the historical and developmental aspects of natural history raised to prominence within Theories of the Earth. Rather than regarding Theories of the Earth as proto-scientific because they were unified only by their object of study, we should recognize that what allowed for the reconfiguration of discourse into new technical disciplines was the fluidity of a mediating textual tradition.[89]

In their general scope, as an overarching discourse, lies the only adequate basis for defining any allegedly essential character for Theories of the Earth.[90] Therefore, the meaning of "theory" in any Theory of the Earth must be interpreted empirically, on a case-by-case basis, where all that may be taken for granted is that the tradition was comprised simply of investigations of more general scope than those which focused upon more particular aspects of the Earth or more confining views of its past. Because of this global vision, Theories of the Earth served an integrating discursive function among diverse audiences, the understanding of which is prerequisite for an holistic understanding of their empirical investigations, disciplinary and professional relations, social and technical practices, and conceptual theorizing. Whether any Theory belonged to the same discipline or research program or whether it rested on similar investigative methodologies, evidential criteria, or privileged interpretations as contemporary disciplines or studies with more restricted aims cannot be prejudged. Any *a priori* "theory" of Theories of the Earth should be regarded as historiographically inadequate.

§ 3-ii. Theories and Texts

The first word in the phrase "Theory of the Earth" has too often set the stage for discussion. That contemporaneous readers and practicing geologists or philosophers of science in later periods should see Theories of the Earth primarily as *theories* is not surprising, given their understandable concern with the content and ideas of Theorists abstracted from the works

[89] Lest it be misunderstood, let me hasten to clarify that my claim in this paragraph that Theories of the Earth as a textual tradition were somehow intermediate between technical disciplines before, during, and after them is non-exclusive. Many of these technical disciplines endured throughout the seventeenth and eighteenth centuries in relative autonomy, and none were simply swallowed up within Theories of the Earth. Rather, Theories of the Earth provided a textual forum in which they could meet up with each other, as explained below.

[90] One still sometimes encounters the erroneous idea that whole-Earth thinking began with continental drift. John McPhee provides a helpful correction, despite limiting his remarks to only two Theorists of the Earth: "As has happened only twice before in geology—with Abraham Werner's neptunist system and James Hutton's Theory of the Earth—the theory of plate tectonics has assembled numerous disparate phenomena into a single narrative." John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), 120–121.

themselves, translated into their own different frames of reference and oftentimes polemical contexts. Yet given the diversity of theories, if one attempts to *define* the tradition by key theoretical features, then paradoxes and contradictions rapidly arise. When essentialist definitions are actually put into practice to identify specific Theories of the Earth, inconsistencies result in obvious false positives (texts mistakenly included) and false negatives (texts mistakenly excluded). For just one example of a false positive, consider Eduard Suess (1831-1914), who provides the epigraph for Part II. Suess wrote extensive theoretical works on the geology and geophysics of the entire globe. Considered in the abstract, his multi-volume masterwork *Das Antlitz der Erde* (1883-1909) was a *theory* of the Earth, and it even begins with scholarly, interdisciplinary *theorizing* about a proposed physical explanation of the Deluge of Noah, relying upon textual, philological, and archaeological evidence as well as fieldwork. Although a modern interpreter might be tempted to identify whole-Earth theorizing invoking biblical evidence as a key feature of Theories of the Earth, nevertheless few would conclude on historical grounds that Suess' work was a holdover from the seventeenth- and eighteenth-century Theories of the Earth textual tradition. To equate *theorizing* about the Earth with Theories of the Earth leads to untenable delineations of the tradition.[91]

One might protest at this point that it may turn out that the theories contained in Theories of the Earth will share a few key identifiable features—although whole-Earth theorizing is not a sufficient criterion, and the serious use of biblical evidence is not necessary. However, any purportedly essential feature must be inferred as the *result* of an empirical delineation of the tradition on other grounds, not stipulated as an *a priori* means of defining Theories of the

91 Eduard Suess, *Das Antlitz der Erde*, 3 vols. (Prag: F. Tempsky; Leipzig: G. Freytag, 1883-1909); Eduard Suess, *The Face of the Earth*, trans. Hertha B. C. Sollas, 4 vols. (Oxford: Clarendon Press, 1904). For a perceptive analysis of Suess' global tectonics see Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World*, Cornell History of Science Series (Ithaca: Cornell University Press, 1982), chapters 6-7. If one were to suggest that Suess' work be regarded as a Theory of the Earth on conceptual grounds (cf. the characterization by Bailey Willis quoted on page 330), then one would no longer have reason to exclude a host of other whole-Earth theorists from Aristotle to Alfred Wegener. The ensuing expansion of the sample base of Theories, on closer examination, would raise further paradoxes and absurdities invalidating any conceptual definition of Theories of the Earth in the first place.

Earth in the first place. Otherwise, conventional interpretations relinquish the epistemic virtue of openness to falsification, abandoning any means of detecting false-negative identifications (*i.e.*, texts artificially excluded from the Theory of the Earth tradition). As noted above, in defense of an overly-narrow definition of Theories of the Earth one may too easily set aside an inconvenient counterexample with the subjectively irrefutable counterclaim: "That is not a Theory of the Earth!" By just such a disjunctive rhetorical maneuver modern interpreters of Theorists as diverse as Steno, Hutton, and Cuvier attempt to separate their subjects' works from any taint of association with this genre of ill repute.[92]

The way out of this conundrum begins with an observation: Before readers debated and responded to any Theory of the Earth as a *theory*, it was first written and published as a *text*. To consider Theories of the Earth as an historical tradition begins with seeing them primarily as texts. In an important sense, the delineation of the tradition has already been accomplished—Theories were contingently constructed as a textual tradition by the historical actors themselves. Their unity is nominal and contingent, not conceptual and essential. Instead of considering theories in the abstract as objects for conceptual analysis or scientific evaluation, the focus in this study centers upon Theories as texts or historical artifacts—piles of books stacked on a reading table, written and read in succession by particular figures at certain times in specific places and in various combinations for all sorts of reasons. To the historian, the production and consumption of these texts reflect repeated, interesting confluences of specific practices associated with divergent scholarly and technical contexts.

To express this contrast between texts and theories in another way, conventional interpreters of Theories of the Earth too often resemble nineteenth-century Platonic taxonomists in their search for the essential archetypes of ahistorically-defined species.[93] To extend the metaphor, the variety of specimens (texts) examined in the field (their specific historical con-

[92] For examples of disjunctive rhetorical maneuvers see page 567 (Steno), page 277 (Hutton), and page 313 (Cuvier).

texts) belies analysis solely in terms of any single type-specimen in the museum of conventional interpretation. The tradition did not await definition according to a key set of essential features formulated as an archetype in the mind of the interpreter-taxonomist, but constituted itself as a diverse and highly adaptive population. Conventional views assume that differences between Theories of the Earth are accidental and therefore their history must be uninteresting. Rather, in contrast to a type-oriented taxonomic mode, a more nominalistic description is called for, one which does not discount the significance of variation within a population and which is attuned to the manifold contingencies attending descent with modification. In short, historically-sensitive descriptions inspect texts before theories, privilege individuals before types, and attend to populations rather than essences.[94]

§ 3-iii. Theories and Facts

Nor would it be appropriate to infer that Theories of the Earth should be contrasted with gathering *facts* about the Earth, as if Earth Theorists had little regard for empirical research. Roger, a sympathetic scholar, observes that in the Theories of the Earth of Buffon's generation, "highly daring hypotheses rubbed shoulders with precise observations."[95] Yet according to Buffon himself, a mutually conditioning interplay between theory and observation characterized his work:

93 The archetypal perspective of Richard Owen is explored by Adrian J. Desmond, *Archetypes and Ancestors: Palaeontology in Victorian London, 1850–1875* (Chicago: University of Chicago Press, 1982). The archetypal thinking of James Dwight Dana is accessibly summarized in Stephen Jay Gould, "Darwin's American Soulmate: A Bird's-Eye View," in *Leonardo's Mountain of Clams and the Diet of Worms: Essays on Natural History* (New York: Harmony Books, 1998), 99–118. A most illuminating expression of archetypal thinking is a novel by Charles Williams, *The Place of the Lion* (London: Faber & Faber, 1952).

94 As should be obvious, my approach to Theories of the Earth draws upon the polarity frequently discussed by Ernst Mayr as "Population Thinking *versus* Essentialism." Cf. Ernst Mayr, *The Growth of Biological Thought: Diversity, Evolution, and Inheritance* (Cambridge: The Belknap Press of Harvard University Press, 1982), 45-46 and chapter 6.

95 Jacques Roger, *Buffon: A Life in Natural History,* trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997), 93.

> …there are two equally dangerous positions: the first is to have no system at all, and the second is to try to relate everything to a restricted system.… [Some] persons start out by purchasing indiscriminately everything that catches their eye.… [Others] labor all their life upon one particular approach and in a false direction, and, desiring to bring everything into their particular point of view, they restrict their minds.…[96]

Buffon's contemporaries and successors were not always persuaded that he had maintained a proper relationship between theory and observation, but those who produced new Theories of the Earth did so in the belief that they were doing so on the basis of increased empirical knowledge. For example, the title of the Theory of the Earth of Noël André (1728–1808), includes the words "impartial" and "actual" (twice), and claims to present researches *fondées, uniquement, sur les faits, sans systême et sans hypothèse*.[97]

To consider another example, at the turn of the nineteenth century in Edinburgh, amidst vigorous local debates between advocates of Neptunist and Plutonist Theories of the Earth, the leading Huttonian John Playfair (1748–1819) insisted that it was "hurtful to the progress of physical science to represent observation and theory as standing opposed to one another."[98] Although he argued against Playfair's system in his *Comparative View of the Huttonian and Neptunian Systems of Geology* (1802), John C. Murray (1778–1820) concluded that in developing "that modification of the Neptunian system which is generally received…

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96 *Initial Discourse,* trans. John Lyon, *From Natural History to the History of Nature* (Notre Dame: Notre Dame University Press, 1981), 107-108.

97 Noël André, *Théorie de la Surface Actuelle de la Terre, Ou plutôt Recherches impartiales sur le temps et l'agent de l'arrangement actuel de la surface de la terre, fondées, uniquement, sur les faits, sans systême et sans hypothèse* (Paris: A la Société Typographique, 1806). Noël André (known as Père Chrysologue de Gy before the Revolution), traveled on foot through the Alps, Jura and Vosges mountains, inspired by Saussure to observe the rocks and terrain. Cuvier commended André's observations, particularly of the Valais, while distancing himself from André's system. Rudwick translates and comments on Cuvier's review, which includes remarkable specimens of anti-theoretical rhetoric (some of which is echoed by Rudwick himself), in Martin J. S. Rudwick, "A Report on André's Theory of the Earth," in *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), 98–111. Cuvier's rhetoric in turns echoes that of D'Alembert in the *Encyclopédie* directed toward Buffon; for D'Alembert see footnote 196 on page 108. Cuvier is discussed in "Controversy and the Rhetoric of Demarcation," beginning on page 307.

98 John Playfair, *Illustrations of the Huttonian Theory of the Earth* (Edinburgh: for Cadell and Davies, London, and William Creech, Edinburgh, 1802), 526; reprinted in facsimile as John Playfair, *Illustrations of the Huttonian Theory of the Earth* (Urbana: University of Illinois Press, 1956; New York: Dover, 1964); hereafter Playfair, *Illustrations*.

its author, Werner, has not indulged in hypothesis, but has approached as nearly to an induction of facts as the subject admits." Thus for Murray, as for Playfair and others, theories were investigations and defenses of frameworks and first principles constituting the grounds of knowledge, rather than unsupported hypotheses or speculation.[99] Murray's systematic comparison of the first principles of each Theory, and the refusal by both Murray and Playfair to employ *fact* vs. *theory* rhetoric contrasting Theories of the Earth to careful induction from observational evidence, exemplify the well-known emphasis of Scottish universities at the turn of the century on probing the theoretical foundations of all knowledge, including inductive knowledge in empirical science.[100]

However, English watchers of the debates carried on by their Scottish neighbors to the north considered them indecorous, and by adopting an anti-theoretical stance of Baconian fact-gathering they enhanced their own stature as uncontentious, reliable readers of the eminently-legible rocks.[101] This pragmatic retreat from natural philosophical and epistemological inquiry was expressed in the foregrounding of a rhetorical distinction between *theories* and *facts* which was utterly incompatible with an understanding of *theories* as concerned with probing the grounds of knowledge. Theories of the Earth were thus robbed of legitimate subject matter, for *theories* of the Earth became uncertain systems based on groundless speculations, as opposed to reliable geology based on careful *observations*.[102] For example, in his

[99] John C. Murray, *A Comparative View of the Huttonian and Neptunian Systems of Geology, in answer to the Illustrations of the Huttonian Theory of the Earth, by Professor Playfair* (Edinburgh: Printed for Ross and Blackwood …; and T. N. Longman, and O. Rees, London, 1802), 12; see Part II, "Of the probability of the First Principles of the Huttonian and Neptunian Theories." Murray's text, widely available in the History of Geology Series of facsimile reprints by Ayer Publishing, is discussed in Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World,* Cornell History of Science Series (Ithaca: Cornell University Press, 1982), chapter 1. Cf. Playfair, *Illustrations,* 527–528: "It cannot, however, be denied, that the impartiality of an observer may often be affected by system; but this is a misfortune against which the want of theory is not always a complete security. The partialities in favour of opinions are not more dangerous than the prejudices against them; for such is the spirit of system, and so naturally do all men's notions tend to reduce themselves into some regular form, that the very belief that there can be no theory, becomes a theory itself, and may have no inconsiderable sway over the mind of an observer. Besides, one man may have as much delight in pulling down, as another has in building up, and may choose to display his dexterity in the one occupation as well as in the other. The want of theory, then, does not secure the candour of an observer, and it may very much diminish his skill."

Outline of Mineralogy and Geology (1816), which repeatedly claimed to be without theory, William Phillips defended his extensive use of the Neptunist system by suggesting that the *reliability* of Werner's conclusions diminished their theoretical character.[103] The triumph of inductivist language defining the "theory" of the Earth as *uncertain* speculation in opposition to reliable empirical study signalled a remarkable collective rhetorical accomplishment: a long-standing tradition of philosophical inquiry was being defined out of existence (at least among geological practitioners within the borders of England). Later, when Charles Lyell attempted to reintroduce discussion of the principles of geological reasoning, some of his English counterparts regarded him as an advocate for a Theory of the Earth.[104]

[100]In *The Democratic Intellect: Scotland and Her Universities in the Nineteenth Century*, 2d ed. (Edinburgh: Edinburgh University Press, 1964), George Elder Davie argues that Scottish science was characterized by an awareness and exploration of its metaphysical foundations—not merely a set of techniques or a method of action, but an intellectual and social pursuit of truth, particularly through geometry. Steven Shapin agrees: "The lament is one of the most highly developed Scottish art forms. By the 1830s and 1840s laments were regularly sounded on the… decline of Scottish science.… Scottish identity was perceived to be under threat from English forms, and in this respect, attitudes towards Scottish science were little different from attitudes towards Scottish education, the use of Scottish literary forms, and the reform of Scottish political institutions along English lines.… It was widely held that Scottish science had declined in scope, in its metaphysical framework, and in general philosophical import. Where once, in its Enlightenment vigour during the eighteenth century, Scottish men of science had produced grand cosmological schemata and inquired into the foundations of scientific knowledge, now, it was claimed, science was in danger of becoming a 'mere mechanical knack.' As Carlyle said of algebra in the 1820s, it was little 'else than a cunningly constructed arithmetical mill'; one simply turned a crank and ground out an answer. Naturalists unfavorably contrasted the zoology and botany of the 1830s and 1840s with the breadth of James Hutton's geology and natural philosophy, Joseph Black's chemistry, and William Cullen's medical theory; all that Scotland produced now, it was claimed, was a 'small philosophy of mosses.' …[They] were not claiming that there was quantitatively less science than there used to be; there was indisputably more. What they meant was that a distinctively Scottish 'philosophical' character of science was being eroded, and that the new science, lacking this dimension, was indistinguishable from science in, for example, England." Shapin concludes that "The 'reform' of Scottish university education was the main agent in the erosion of a distinctively Scottish intellectual tradition." Steven Shapin, "Science," in *A Companion to Scottish History,* ed. David Daiches (New York: Holmes and Meier Publishers, 1982), 318. Cf. G. N. Cantor, "Henry Brougham and the Scottish Methodological Tradition," *Studies in the History and Philosophy of Science* 2 (1971–1972): 69–89; J. B. Morrell, "Reflections on the History of Scottish Science," History of Science 12 (1974): 81–94; John R. R. Christie, "The Rise and Fall of Scottish Science," in *The Emergence of Science in Western Europe,* ed. Maurice Crosland, 111–126 (New York: Science History Publications, 1976); and R. H. Campbell and Andrew S. Skinner, eds., *The Origins and Nature of the Scottish Enlightenment* (Edinburgh: John Donald Publishers, 1982).

[101]Henry Thomas Buckle reflected English attitudes toward the "Athens of the North" when he argued that "the Scotch intellect" was wrong-headedly deductive with its emphasis on first principles rather than proceeding soundly by induction. This habit derived, Buckle surmised, from the domination of Scotch culture by the deductively-minded Presbyterian clergy. English science, Buckle warned, was being penetrated by these destructive Scotch tendencies. Buckle, *On Scotland and the Scotch Intellect* (1857-61); vol. 3 of *Civilisation in England*. For a contrary Scottish perspective, cf. Robert Louis Stevenson, "The Foreigner at Home" (1811, often reprinted).

Following the example of the early English geologists, the *fact* vs. *theory* polarity continues as a major rhetorical trope in the historiography of Theories of the Earth. In a typical example, one historian suggests that the diversity of Theories of the Earth circa 1800 demonstrates that "too many theories were chasing too few facts."[105] Although there is some degree of truth in this common-sense explanation for the lack of consensus in a contested tradition, it is equally plausible, *a priori,* to turn such rhetoric on its head and suggest that the proliferation of Theories also reflected a *superabundance* of newly available facts, which required the

[102]The word "theory" is still deployed with similar rhetorical ambiguities. For example, in 1999 Alabama and several other states inserted notices in high-school biology textbooks to remind students that evolution is "only a theory," not a fact, since no one was there to observe it. On the other hand, the National Academy of Sciences has weighed in against the creationists (and, we might add, the English geologists) with a clarification of its reference to the framework and first principles of knowledge: "In science, the word 'theory' means something quite different. It refers to an overarching explanation that has been well substantiated… Sometimes scientists themselves use the word 'theory' loosely and apply it to tentative explanations that lack well-established evidence. But it is important to distinguish these casual uses of the word 'theory' with its use to describe concepts such as evolution that are supported by overwhelming evidence. Scientists might wish that they had a word other than 'theory' to apply to such enduring explanations of the natural world, but the term is too deeply engrained in science to be discarded"; *Teaching about Evolution and the Nature of Science* (Washington, D.C.: National Academy Press, 1998), 4–5. Cf. the review by Edward J. Larson, "Evangelists for Science," *Isis* 90 (1999): 558–559.

[103]Phillips explained: "If Werner be actually a theorist, he is one of a superior order. He has extended his researches throughout the large and important district surrounding him. The relative age, deduced from the relative position, internal structure and contents of the great masses forming that mountainous district, seems to have been *ascertained by him with a degree of certainty that defies the application of the term theory to his results*. If he merit the name of theorist at all, it seems only to be in consequence of his assertion, or supposed assertion, (for hitherto his principal discoveries have been communicated only by some of his pupils) that the same results will be found to prevail universally. It is certain that researches in almost every quarter of the globe, have tended in an astonishing degree to verify his opinions, that order in regard to deposition is universally prevalent, and that this order is never inverted." Phillips, 117-118. Italics added; original italics removed. Incidentally, this quote suggests that Phillips believed many of his readers would regard Werner as a Theorist, as discussed below, page 116. Phillips is analyzed below, on page 351.

[104]For example, William Henry Fitton's favorable essay review of Lyell's *Elements of Geology* was in part titled the "Huttonian Theory of the Earth," *Edinburgh Review* 69 (1839): 406–466; cf. Figure 31 on page 274. Critics likewise noted a resemblance; for example, after the publication of Lyell's *Principles*, Henry Thomas De la Beche drew a series of sketches which caricatured Lyell as a Theorist concealing a Theory of the Earth behind his back while observing geological phenomena through theory-tinted spectacles. De la Beche's sketches are reprinted and discussed in Martin J. S. Rudwick, "Caricature as a Source for the History of Science: De la Beche's anti-Lyellian Sketches of 1831," *Isis* 66 (1975): 534–560; one is reprinted as Figure 2.7 in Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), 38. Some historians have described Lyell's work as including a "theory of the Earth" with "speculative" components; e.g. Dov Ospovat, "Lyell's Theory of Climate," *Journal of the History of Biology* 10 (1977): 317–339; cf. footnote 49 on page 285 below. The literature analyzing Lyell's principles of geological reasoning may be sampled in Michael Ruse, "Charles Lyell and the Philosophers of Science," *British Journal for the History of Science* 9 (1976): 121–131; and Rachel Laudan, "The Role of Methodology in Lyell's Science," *Studies in the History and Philosophy of Science* 13 (1982): 215–249.

[105]Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 27.

development of new theories for their interpretation. That this was the view of many Theorists themselves is illustrated by Playfair's remark that

> It cannot be denied, that a great multitude of facts, respecting the mineral kingdom, are now known with considerable precision; and that the many diligent and skilful observers, who have arisen in the course of the last thirty years, have produced a great change in the state of geological knowledge. It is unnecessary to enumerate them all; Ferber, Bergman, De Luc, Saussure, Dolomieu, are those on whom Dr. Hutton chiefly relied; and it is on their observations and his own that his system is founded.[106]

In any case, Theories of the Earth did not decline as a result of the explosion of novel facts obtained in the eighteenth century, but multiplied right along with (and evidently as part of) the Enlightenment "ferment of knowledge."[107] If our perspective reaches beyond that of the early English geologists, then when dealing with Buffon, Hutton, Werner or any other Theorist we will understand but little of their historical character if we try to distinguish Theories of the Earth from contemporary writings by means of an analytical dichotomy of *theory* vs. *fact,* and nothing at all if we simply dismiss them wholesale as an endeavor of unfounded "speculation."

It is worth noting that the early English geologists did not invent the *fact* vs. *theory* trope linked with the pejorative sense of the word "speculation." Not all Theorists shrank from using the latter word; some defended the methodological legitimacy of speculation in at least some restricted form.[108] A few, such as Agostino Scilla, excoriated the ideas of their opponents as based on speculations rather than empirical observations, denying that their own works were tainted with any speculative component whatsoever.[109] But most who decried the blindness of unwarranted theorizing did so with the agenda of properly grounding theory

[106]Playfair, *Illustrations,* 514. I suggest that a superabundance of facts arose in part because of the fruitfulness of the very theories that ultimately failed to encompass them. Ospovat builds a similar case with respect to the basalt controversy; Alexander M. Ospovat, "Abraham Gottlob Werner and His Influence on Mineralogy and Geology" (Ph.D. dissertation, University of Oklahoma, 1960).

[107]The explosive growth of empirical natural knowledge during the eighteenth century is well known; see Roy S. Porter, "The Terraqueous Globe," in *The Ferment of Knowledge: Studies in the Historiography of Eighteenth-Century Science*, ed. G. S. Rousseau and Roy Porter, 285–326 (Cambridge: Cambridge University Press, 1980), 285–326.

rather than banishing it altogether; such was the case with Cuvier's rejection of Noël André's Theory in 1806, a half-dozen years before he was prepared to propound his own, or with Bernard Palissy's use of the dialogue format where he adopted the allegorical voice of Observation to instruct (not to dismiss) the submissive and teachable Theory.[110] In both historical polemics and modern historiography, "speculation" is used to suggest an intellectualist, rationalist, deductive, even *a priori* endeavor, which utterly discounts empirical and historical evidence. Yet no Theorist after Descartes claimed to rely upon reason alone or to advance empirically-unsupported conjectures.[111] The meaning of "speculation" was altogether vague and contradictory; because it has long been employed to caricature Theories of the Earth, "speculation" henceforth should be analyzed as an actors' category, and otherwise dropped from the historian's vocabulary.[112] "Speculation" lay in the eye of the beholder; what seemed like a promising method of inquiry to one writer was dismissed as unfounded speculation by the next. A miner or fieldworker might regard evidence from laboratory experiments or from cosmology and physics as speculative, while the chemical mineralogist in turn might dismiss the mathe-

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[108]E.g., François Para du Phanjas, *Theoria Entium Sensibilium, sive Physica Universa Speculativa, Experimentalis, Systemica et Geometrica, omnium captui accommodata*, 4 vols. (Venice: apud Laurentium Basilium, 1782–1783), or Robert Jameson, "Mineralogical Observations and Speculations," *Memoirs of the Wernerian Natural History* Society 2 (1818): 221–231. Nor is conjecture and speculation entirely out-of-bounds in modern geological practice. For example, Harry Hess confessed in the beginning of his revolutionary essay on the "History of Ocean Basins" (which introduced the idea of the spreading sea floor so critical for plate tectonics) that his arguments were an "essay in geopoetry." The acclaimed journalist John McPhee's methodological observations accord with the historical character of geological inference: "All science involves speculation, and few sciences include as much speculation as geology. Is the Delaware Gap the outlet of a huge lake all other traces of which have disappeared? A geomorphologist will tell you that, in principle, the idea is O.K.... In oil drilling, you had better be ready to act shrewdly on the basis of partial information. Do physicists do that? Hell, no. They want to have it to seven decimal places on their Hewlett-Packards. The geologist has to choose the course of action with the best statistical chance. As a result, the style of geology is full of inferences, and they change. No one has ever seen a geosyncline. No one has ever seen the welding of tuff. No one has ever seen a granite batholith intrude." John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), 133.

[109]Agostino Scilla, *La vana speculazione disingannata dal senso* (Naples: Appresso Andrea Colicchia, 1670).

[110]For Cuvier, see the discussion in "Controversy and the Rhetoric of Demarcation," beginning on page 307. On Palissy, see "Aristotelian Theories of the Earth," beginning on page 188; cf. Bernard Palissy, *Discovrs admirables, de la natvre des eavx et fonteines, tant natvrelles qv'artificielles, des metaux, des sels & salines, des pierres, des terres, du feu & des emaux* (Paris: M. le Ieune, 1580).

[111]Even Descartes' reasoning, despite its deductive form, actually incorporated a substantial amount of contemporary natural knowledge; cf. Spyros Sakellariadis, "Descartes's Use of Empirical Data to Test Hypotheses," *Isis* 73 (1982): 68–76; and below, page 615ff.

matical abstractions of a physicist, just as a Newtonian physicist might scorn the non-quantitative Cartesian system. And an antiquarian (or geognost) might dismiss all of the above as merely *a priori* speculation about possible worlds rather than actual events unless the *a posteriori* evidence of historical texts and artefacts (or fieldwork) was taken into account. Indeed, much of the concern of Theories of the Earth was to negotiate precisely which *kinds* of empirical evidence (natural and historical), methodological aims, and rational principles (philosophical and epistemological) were most pertinent and reliable for the questions they sought to resolve. On these issues there was little agreement, and as a consequence the tradition was discordant, contested, and controversial.

For two centuries, writers resourcefully marshalled the best investigative techniques available from a variety of technical, disciplinary, and scholarly contexts. Problem sets, methods of inquiry, and standards of proof were appropriated from many different contexts. Theories of the Earth provided a "public sphere" for interactions between these various discourses.[113] "Outsiders" with respect to a given context challenged the tacit assumptions of "insiders," and were then in turn challenged by others who were not "insiders" to their own context. The

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[112] Among the many, often-contradictory meanings of "speculation" listed in the *Oxford English Dictionary.* the first is most significant as a precautionary warning to historians: "I.1. The faculty or power of seeing; sight, vision, esp. intelligent or comprehending vision. Now arch[aic].... 1821 Shelley *Ginevra* 149 Open eyes, whose fixed and glassy light Mocked at the speculation they had owned." The OED cites the *Philosophical Transactions* of the Royal Society of London in 1693: "The square Tower in the middle was lined with Holes for Speculation," 691. A second definition (2b) is "Observation of the heavens, stars, etc." The OED illustrates this meaning of speculation with a reference to Tycho Brahe, the great observational astronomer: "1617 Moryson *Itin*. 1.59 He had a little round house of great beauty, in which he did exercise his speculation." Another definition (II. 4.) is "The contemplation, consideration, or profound study of some subject," and cites Ralph Cudworth, *Intell. Syst.* (1678) 1.IV. 416, "Furthermore Aristotle declares, that this Speculation concerning the Deity, does constitute a particular science by itself." The fact that these definitions have a quite different emphasis and connotation than later ones such as "hypothetical reasoning on subjects of a deep, abstruse, or conjectural nature," and "As opposed to practice, fact, action, etc.," suggests that historians should regard speculation as an actors' category, and altogether avoid its uncritical disparaging use.

[113] I am appropriating Goodnight's distinction between the "public" and "technical" spheres and recasting them not as mutually insulated domains but as a continuum between textual and technical traditions (see below); cf. G. Goodnight, "The Personal, Technical, and Public Spheres of Argument: A Speculative Inquiry into the Art of Public Deliberation," *Journal of the American Forensic Association* 18 (1982): 214–227. The literature on spheres of discourse is discussed with special attention to scientific rhetoric in Charles Alan Taylor, *Defining Science: A Rhetoric of Demarcation,* Rhetoric of the Human Sciences (Madison: University of Wisconsin Press, 1996), 122–130. My analysis of Theories of the Earth supports Taylor's anti-demarcationist thesis regarding the formation of technical spheres, that "what counts as the relevant probative context is a rhetorical accomplishment" (p. 126).

resulting ideological and methodological struggle for existence resulted in a dialectical development of the Theory of the Earth tradition which eventually, with fits and starts, shaped the emergence of various nineteenth-century disciplines and professional fields (including the contractionist global tectonics practiced by Suess).

§ 3-iv. Theories and Practices

A fourth disclaimer is related to the distinction between a Theory of the Earth and *theorizing* about the Earth. As is well-known, Alexandre Koyré argued for the driving force of theory, rather than observation and experiment, in the Scientific Revolution.[114] That kind of history of ideas is not my intention here. Despite the often-remarked tendency of traditional histories of ideas to reify unit-ideas, isolating theories from their local contexts of observation, evidence, and practice, masterful studies of the long-term significance of philosophical ideas and background presuppositions have thrown much-needed light upon Theories of the Earth and historical sensibilities.[115] We have seen that theoretical aspects of historical inferences in the Earth sciences are often overlooked. Yet John Murray argued that the contests between the Huttonian and Wernerian theories of the Earth were beneficial to the progress of science:

> Systems, says a geological writer, are in the sciences what the passions are in the human mind: they may be the source of great errors, but they are the cause also of great exertions. Either in defending or opposing them, it is necessary to observe with accuracy, to compare and generalise; objects apparently minute, acquire an

[114]Alexandre Koyré, *Études Galiléennes* (Paris: Hermann, 1939); Alexandre Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins University Press, 1957); Alexandre Koyré, *Metaphysics and Measurement* (Cambridge: Harvard University Press, 1968).

[115]A classic statement and example of the history of ideas is Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936). An insightful critical defense of intellectual history (including specific corrections to Lovejoy's analysis of his own chosen complex of ideas) is Francis Oakley, *Omnipotence, Covenant, and Order: An Excursion in the History of Ideas from Abelard to Leibniz* (Ithaca: Cornell University Press, 1984). Both of these works, as well as the many publications of Jacques Roger, John C. Greene, and Phillip R. Sloan, among others, exemplify the successful application of the methods of intellectual history to the issues of Theories of the Earth and historical sensibilities. A helpful reorientation of the aims of intellectual history in light of common criticisms is William J. Bouwsma, "From History of Ideas to History of Meaning," *Journal of Interdisciplinary History* 12 (1981): 279–291.

> interest and importance; views are suggested which often lead to real acquisitions; facts are arranged which would have remained isolated; and relations traced which would not have been observed.[116]

In a similar vein, the geologist W. M. Davis argued for the benefits of outrageous geological hypotheses.[117] In order to constrain the unconscious bias of ruling theories, T.C. Chamberlain argued not for banishing theories, but for simultaneously entertaining multiple working hypotheses so that the geologist obtains the "power of simultaneous vision from different standpoints."[118] The significance of cognitive theorizing is an important part of the story of Theories of the Earth, yet as should be evident from the foregoing discussion, to argue for the significance of Theories of the Earth to the development of historical sensibilities, an intellectual historian need not proceed by presupposing an essential priority of theory for the development of natural knowledge.

Koyré's neo-Kantian historiography of science may be understood as a reaction against positivist views of the development of scientific knowledge which stipulated a gradual accumulation of observational facts ascertained by an inductive, non-hypothetical scientific method.[119] Such positivism is embodied in many internalist histories (particularly those

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[116]John Murray, *The Huttonian and Neptunian Systems of Geology*, 1802, v. Cf. Playfair's remark in footnote 99 on page 54.

[117]W. M. Davis, "The Value of Outrageous Geological Hypotheses," in *Philosophy of Geohistory*, Benchmark Papers in Geology (Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc., 1975), 147–152, originally published in *Science* 63 (1926): 463–468. Davis suggested (p. 148/464) that "as the great advances of physics in recent years and as the great advances in geology in the past have been made by outraging in one way or another a body of preconceived opinions, we may be pretty sure that the advances yet to be made in geology will be at first regarded as outrages upon the accumulated convictions of to-day, which we are too prone to regard as geologically sacred."

[118]Thomas C. Chamberlin, "The Method of Multiple Working Hypotheses," in *Philosophy of Geohistory*, Benchmark Papers in Geology (Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc., 1975), 126–131, originally published in *Science* 148 (1965): 754–759; p. 128/756. Chamberlin explains (p. 127/755): "The advocates of reform insisted that theorizing should be restrained, and efforts directed to the simple determination of facts. The effort was to make scientific study factitious instead of causal. Because theorizing in narrow lines had led to manifest evils, theorizing was to be condemned. The reformation urged was not the proper control and utilization of theoretical effort, but its suppression.... The vitality of study quickly disappears when the object sought is a mere collection of dead unmeaning facts."

[119]For a brief overview of the logical positivism of the Vienna Circle and the twentieth-century logical empiricist philosophy of science, see the first part of Harold I. Brown, *Perception, Theory and Commitment: The New Philosophy of Science* (Chicago: University of Chicago Press, 1977). Brown argues that the history of twentieth-century philosophy of science, with the transition from positivism to post-Kuhnian philosophy of science, represents a Kuhnian scientific revolution within the discipline of the philosophy of science itself.

written by practitioners themselves) which proceed by chronicling the factual discoveries of a modern scientific discipline.[120] Anti-positivist concerns still echo, for example, in the arguments of Norriss Hetherington for the primacy of theory in driving the progress of an empirical discipline such as observational astronomy.[121] Geology possesses an empirical character similar to observational astronomy, yet geology is more data-rich; these characteristics are sometimes taken to confirm its descriptive, atheoretical, and positivist reputation.[122] Thus it is not surprising that much historiography of geology has been both openly internalist and written according to positivist assumptions about the growth of knowledge. Ghosts of positivism even haunted the work of Jacques Roger, a classical historian of ideas, in that he seemed

[120] The positivist orientation of George Sarton and other founders of the history of science in the early twentieth century is well known. See, for example, chapter one of Norriss S. Hetherington, *Science and Objectivity: Episodes in the History of Astronomy* (Ames, Iowa: Iowa State University Press, 1988). The portrayal of Theories of the Earth within disciplinary histories of geology is examined in greater detail below; see "Lyell and Histories of Scientific Disciplines," beginning on page 280.

[121] Norriss S. Hetherington, *Science and Objectivity: Episodes in the History of Astronomy* (Ames, Iowa: Iowa State University Press, 1988); this book grew out of an original article, Norriss S. Hetherington, "Just How Objective is Science?" *Nature* (1983): 2–3.

[122] My characterization of geology as empirical and data-rich relies upon Henry Bauer, but the contrast with observational astronomy should not be overstated. Attempting to capture the diversity of scientific methods, Bauer describes different sorts of science in terms of a variety of contrasts (young/mature; data-rich/data-poor; experimental/observational; frontier/textbook; etc.). Bauer suggests that chemistry and geology are data-rich; cosmology and paleoanthropology are relatively data-poor sciences. Bauer notes that his contrasts are independent variables so that, for instance, a mature science is not necessarily data-rich; chemistry is more data-rich than the more mature science of physics (wherein the results of many experiments may be calculated more quickly than the experiments may be performed). See Henry H. Bauer, *Scientific Literacy and the Myth of the Scientific Method* (Urbana: University of Illinois Press, 1992), chapter 2, esp. 29-32. Positional astronomy is often rich in quantitative data, but geological evidence is less amenable to purely quantitative interpretations: "Geologists are always faced with a complex richness of data that offers continuing challenges even to meaningful categorization, let alone explanation..." (p. 31). In contrast to geology's richness in complex data, early non-quantitative planetary observations—although perhaps equally complex in their interpretation—were relatively data-poor (e.g., seventeenth-century attempts to infer an irregular surface of the Moon or to discern the cause of the "handles" or "ears" around Saturn; Hershel's attempts to interpret his initial sightings of Uranus as an approaching comet; Percival Lowell's attempts to describe the seasonal variations of the Martian canals; etc.). Bauer concludes that (p. 31–32) "some scientists do a lot of speculating, whereas others do virtually none, and there is no warrant to call one approach scientific and the other not. It is just the case that different aspects of nature yield to investigation at different rates and in different ways, and so scientists come to differ in all manner of things.... What is true or fruitful for a field that is mature, data rich, and relatively quantitative (thermodynamics, say) is scientific for that specialty even though it may be entirely inappropriate and therefore unscientific for a field that is young, descriptive, and data poor (some bits of planetary science, say)." Although Bauer has no sympathy for positivist views of scientific method, he makes the usual inference (contested by Kitts, as discussed above) that geology's richness in complex data compels practitioners to be patient as they carry on with atheoretical description. However, an increasing richness in complex data does not necessarily correlate with a diminished theoretical endeavor; in Theories of the Earth increasing theoretical activity often correlated with the assimilation of fruitful new lines of evidence (e.g., Whiston and Newtonian cometary physics; Werner and geognostical fieldwork; Cuvier and fossil comparative anatomy; Agassiz and evidence of glacial activity; etc.).

to concede a sharp and rigid distinction between Theories of the Earth and geology, regarding the former as a speculative genre while leaving the latter's positivist methodology intact. That is, Roger's arguments for the *validity* of theorizing in the *proto*-Earth-sciences were circumscribed in part by his tacit concession for later periods of the positivist agenda he explicitly rebutted in his own area of expertise.[123]

Another response to the ghosts of positivism is found in the more recent emphasis on *practice* as underlying and conditioning theory.[124] This trend rejects the abstract analysis of the structure of scientific theorizing which typified logical positivism and logical empiricist traditions in twentieth-century philosophy of science. Although it differs radically from positivism by dismissing claims for scientific certainty and the cumulative growth of scientific knowledge, in one sense it returns to a positivist emphasis on material discovery. The emphasis on practice repudiates both the philosophical aims associated with rational reconstruction as a means for justifying theoretical schemes and the Neo-Kantian metaphysical analysis of the world-views in which various theoretical efforts pitch their tents. Philosophical approaches, whether positivist narratives or neo-Kantian history of ideas, have fallen out of style, and historians of science now distinguish their work from both logical empiricist and idealist philosophical analysis by seeking to constrain their intellectual histories with emphases on actors' categories, social contexts, and the local production of knowledge. In this light, Martin J. S. Rudwick's apparent distaste for the Theories of the Earth tradition is charitably understood as reflecting a sympathy for socially-informed attention to praxis.[125]

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[123] This aspect of Roger's definition of Theories of the Earth is explored below on page 346.

[124] For representative approaches see the various essays contained in Andrew Pickering, ed., *Science as Practice and Culture* (Chicago: University of Chicago Press, 1992).

[125] An attention to praxis has characterized much of Rudwick's work, including Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), and Martin J. S. Rudwick, "Senses of the Natural World and Senses of God: Another Look at the Historical Relation of Science and Religion," in *The Sciences and Theology in the Twentieth Century*, ed. Arthur Robert Peacocke (South Bend: Notre Dame University Press, 1981), 241–262.

Similarly, Hugh Torrens has warned of the dangers of papyrology, an exclusive focus upon ideas found in texts. His point is well taken that to understand the development of early geology we need to understand the work of many practitioners who never made it into print. Yet to speak of a textual tradition does not force us to choose between studying either ideas OR practices, for texts embodied practices as well as ideas. Theories of the Earth represent diverse and cross-disciplinary practices. Non-literary practices received greater attention with the publication of a Theory which deployed them, as when Whiston's Theory popularized Newton's mathematical physics, or Cuvier's Theory disseminated his techniques of comparative anatomy. The same could be said for a multitude of other contexts, including mining, mineralogy, natural history, or even technical chronology, philology, and associated aspects of classical scholarship.

These developments are welcome: the historiography of science has been enriched by the lessening of reified abstractions and the contributions of a variety of additional perspectives.[126] In any case, the antithetical conclusions resulting from Roger's idealist analysis in support of the Relevance Thesis and Rudwick's praxis interpretations disputing it remain the point of departure for any critical discussion of the historiography of Theories of the Earth. However, any alleged dichotomy between theory and observation, or between theory and practice, plays no part in the present analysis which emphasizes delineating the tradition in light of historical contingencies rather than defining it by philosophical criteria or alleged essential concepts. "Theory" is a dangerous word, susceptible of covert and misleading associations. Herein Theory (capital "T") refers to a text, not an idea; contrary to what might be assumed, questions of empirical investigation, technical practice, and social context also fall

[126]This claim endorses neither side of the so-called "science wars," an affair which sadly perpetuates an extreme polarization into two cultures where neither side allows for methodological pluralism. Cf. a chronology of the science wars and related pages; Kerry Magruder, "Two Cultures of Science Studies," http://www.earthvisions.net/hsci/scienceStudies/index.html.

within the purview of historical attempts to better understand what the writers and readers of these texts were about.

With respect to historical sensibilities and Theories of the Earth, two eminent and distinguished historians have come to diametrically opposed views. How can Roger and Rudwick disagree so completely? Their disagreement does not result from using different terminology for historical sensibilities: both Rudwick and Roger distinguish historical contingency from genetic formation as we have defined them. Nor do they define Theories of the Earth differently: both regard Theories of the Earth as a conceptually-defined mentality, rather than a textual tradition delineated by the historical actors. Indeed, just this kind of disagreement is typical of the untenable contradictions that arise when any historian defines Theories of the Earth as a conceptual mentality and then resorts to disjunctive rhetorical maneuvers with respect to whether particular texts by one's own subject (specifically Cuvier's) were indeed Theories of the Earth. I suggest that historians should step back from the Theorists' own conceptual debates, without taking sides, and regard the tradition as a textual tradition constituted by the debates themselves. Delineating Theories of the Earth as a textual tradition avoids definitional paradoxes, and allows us to investigate how it was that debates about natural order and historical contingency in the Earth's past became of central importance to Theorists of many types, including Buffon, Hutton, and Cuvier.

We will turn to an historical delineation of that textual tradition after two additional clarifications of the distinction between textual and technical traditions.

§ 3-v. Natural Knowledge and Textual Traditions

> And again, if a man turn from the workshop to the library, and wonder at the immense variety of books he sees there, let him but examine and diligently inspect their contents, and his wonder will assuredly be turned the other way. For after observing their endless repetitions, and how men are ever saying and doing what has been said and done before, he will pass from admiration of the variety to astonishment at the poverty and scantiness of the subjects which till now have occupied and possessed the minds of men.
>
> *Francis Bacon*[127]

In the spirit of Bacon, it is widely accepted that geology emerged in the early nineteenth century when interpretations of ancient texts, particularly Genesis, were no longer regarded as the primary source of authoritative information about the Earth's past, and thus were replaced by first-hand observations of the Earth itself. At least this was the viewpoint advocated by proponents of a developing professional discipline who regarded Theories of the Earth as incurably tainted with outmoded textual practices rather than employing stratigraphical and other empirical techniques.

This "Baconian" characterization has much to commend it, yet as it stands it is simplistic and in need of significant revision. It is manifest in the antipathy of Charles Lyell toward nineteenth-century English and American "scriptural geologists" who still defended ideas of a young Earth (Table 6).[128] The scriptural geologists' primary reliance upon Moses bore too

TABLE 6. Works of "Scriptural Geology," advocating a Young Earth[a]

Date	Author	Title
1820	"Philobiblos"	Defence of the Veracity of Moses
1822	Granville Penn	Comparative Estimate of the Mineral and Mosaic Geologies
1826	George Bugg	Scriptural Geology
1828	Granville Penn	Conversations on Geology
1833	George Fairholme	General View of the Geology of Scripture

[127]An immense variety of books by Francis Bacon are available for diligent inspection in libraries around the world; Francis Bacon, *The Works of Francis Bacon,* ed. James Spedding, R. L. Ellis and D. D. Heath, 14 vols. (London, 1859–64). Quoted in Anthony Grafton, *New Worlds, Ancient Texts: The Power of Tradition and the Shock of Discovery,* with April Shelford and Nancy Siraisi (Cambridge: The Belknap Press of Harvard University Press, 1992), 202; hereafter "Grafton, *New Worlds, Ancient Texts*."

TABLE 6. **Works of "Scriptural Geology," advocating a Young Earth**[a]

Date	Author	Title
1833	Frederick Nolan	Analogy of Revelation and Science Established
1834	Henry Cole	Popular Geology Subversive of Divine Revelation
1834	Samuel S. Schmucker	Elements of Popular Theology
1836	Thomas Gisborne	Considerations on the Modern Theory of Geology
1836	Moses Stuart	Critical Examination of Some Passages in Genesis I
1837	George Fairholme	The Mosaic Deluge
1838	James Mellor Brown	Reflections on Geology: Suggested by the perusal of Dr. Buckland's Bridgewater Treatise
1838	George Young	Scriptural Geology
1838	William Rhind	Age of the Earth, Considered Geologically and Historically
1840	George Young	Scriptural Geology
1843	Robert M. MacBrair	Geology and Geologists
ca. 1848	Anonymous	Scriptural Evidences of Creation
1849	Hiram Chase	A Treatise on Cosmogony and Geology
1849	William Gillespie	The Theology of Geologists
1851	David King	Principles of Geology Explained
1851	Eleazar Lord	The Epoch of Creation
1853	Anonymous	Brief and Complete Refutation of the Anti-Scriptural Theory of Geologists
1855	David N. Lord	Geognosy
ca. 1855	Thomas Hutton	Chronology of Creation
1856	Anonymous	Reconciliation of Geological Phenomena with Divine Revelation
1856	Martin Paine	Review of Theoretical Geology
1857	Philip Henry Gosse	Omphalos
1857	Thomas A. Davies	Cosmogony, or the Mysteries of Creation

a. Works cited by Milton Millhauser, "The Scriptural Geologists: An Episode in the History of Opinion," Osiris 2 (1954): 65–86.

great a resemblance to references to Genesis by many Theorists of the Earth to allow the latter to escape unscathed by empirical critiques of the former. Theories of the Earth were caricatured by casting scriptural geology as their chief contemporary residue. With adequate rhetorical imprecision, the same denunciation would do for both, the contemporary presence of

[128] Milton Millhauser, "The Scriptural Geologists: An Episode in the History of Opinion," *Osiris* 2 (1954): 65–86.

the one serving to obscure and discredit any past contributions of the other.[129] For example, of attempts to employ the Mosaic deluge to explain the strata, Lyell wrote: "Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts."[130] In contrast, Lyell claimed that only when Theories of the Earth were replaced in the early nineteenth-century by careful geological observations did geology first become a progressive science: "Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions."[131]

Lyell's dim view of the significance of Genesis for geology has been shared not only by later geologists and historians of geology, for whom it has become almost a universal refrain, but also by historians and historians of science, many of whom have lamented the ossifying influence of encrusted biblical discourse generally, apart from geological matters. For example, in a perceptive study, "The Sense of the Past in English Scientific Thought of the Early Seventeenth Century," William Ashworth acknowledges that "the bones of Genesis served as a skeleton for discourses on everything under the sun (once, of course, the sun had been created)." Yet Ashworth summarily declares that: "Perhaps the principal obstacle to the growth of cultural history in the 16th century was the hexameral literature."[132]

It is widely believed that the authority attributed to the hexameral tradition deterred and restricted particular scientific investigations. A plausible case for such detrimental effects

[129]Similarly, current creationist controversies may compromise the historical sympathy of some American observers toward Theories of the Earth.

[130]Lyell, *Principles of Geology,* 29–30. For a contrasting assessment see Rhoda Rappaport, "Geology and Orthodoxy: The Case of Noah's Flood in 18th-Century Thought," *British Journal for the History of Science* 11 (1978): 1–18.

[131]Lyell, *Principles of Geology,* 73.

[132]Ashworth, "Sense of the Past," 42. Ashworth presents a persuasive argument for the significance of the "historical revolution" of the seventeenth century, particularly as it pertained to the development of archaeology, for the development of a "sense of the past." By citing his casual comment here (which pertains specifically to senses of the human past rather than to that of the Earth itself), no disagreement with his specific claim or general conclusions is intended. Yet because this comment was offered almost as a jocular aside, it is all the more revealing of widespread attitudes regarding the hexameral literature.

upon the growth of natural knowledge may be constructed by emphasizing the fact that innovative figures such as Galileo, Descartes, and Buffon encountered censorship by established religious authorities, and the scriptural geologists of Lyell's day garnered a significant degree of popular support which arguably jeopardized efforts to socially legitimize a new profession of geology. More typically, one might point out that the inertia and rigidity of traditional interpretations often diminished the receptivity with which novel ideas might be entertained (*e.g.*, questions regarding the motion of the Earth and its antiquity).[133] Or at a minimum, one might appeal to Augustine's "handmaiden thesis," which by regarding theology as the queen of the sciences at times relegated the serious pursuit of scientific knowledge to a low priority bordering on irrelevance.[134]

At least it is well-known that by 1800 no serious natural historian or natural philosopher believed that classical texts, whether Ovid or Genesis, provided a complete picture of the Earth's past. (Contrary to what might be thought, this statement does not apply to many

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[133] Galileo's *Dialogo* was put on the Index of Prohibited Books in 1633, Descartes' works were added in 1663, and Buffon published a set of retractions to his Theory of the Earth at the request of Sorbonne theologians in 1753. On the theological "baptizing" of Cartesian philosophy see "The Cartesian-Hexameral Birth of the World," beginning on page 541; on Buffon's retractions see footnote 43 on page 384.

[134] A typical invocation of the handmaiden thesis as handicapping the growth of science is Leibniz's lament over Steno: "He was a great anatomist and deeply versed in natural science; but he unfortunately gave up research therein, and from being a great physicist he became a mediocre theologian." Gottfried Wilhelm Leibniz, *Theodicy: Essays on the Goodness of God, the Freedom of Man and the Origin of Evil*, trans. E. M. Huggard, ed. Austin Farrer (Chicago: Open Court, 1985), 178. Of course, one would not expect an intellectualist theologian like Leibniz overly to praise the theology of someone whose philosophical and theological inclinations were Gassendian and voluntarist, however much Leibniz may have followed Steno's ideas in developing his own Theory of the Earth. However, detrimental effects arising from this plausible thesis actually prove quite difficult to substantiate in the seventeenth century. Ambiguities arise with, for example, the Puritan emphasis on the restoration of all things with its work ethic extending to the glorification of God and benefit of humanity by avoiding idleness in the study of his works, and the Jesuit commitment to mathematical sciences; all this despite the Puritans' commitment to a Protestant form of scholastic theology in which the Ptolemaic universe was still largely taken for granted, and the Jesuit reconciliation of Tychonic cosmology with their vows to teach nothing novel—*i.e.*, contrary to Aristotle or Aquinas. In any case, it should be remembered that the handmaiden thesis implies harmony between science and religion, at least to some extent, in significant contrast to a conflict model. For a general account of the handmaiden thesis see David C. Lindberg, "Science as Handmaiden: Roger Bacon and the Patristic Tradition," *Isis* 78 (1987): 518–536. Moreover, opposition to "curiosity" and "vain knowledge" was more often motivated by factors other than the hexameron. Levine has explored the role of the rhetoric of vain presumption as a weapon used in the collision between the pedagogical aims of gentlemanly ideals, suitable for producing a governing class, and movements for curricular reform reflecting scholarly ideals, suitable for the practice of technical disciplines such as philology; cf. Joseph M. Levine, *The Battle of the Books: History and Literature in the Augustan Age* (Ithaca: Cornell University Press, 1991).

early modern scholars, either.[135]) Interpretations of the clues and propositions contained in ancient texts, for those disposed to attempt it, required a primary reliance upon mineralogy or other extra-textual evidence. With this in mind some, seeking to draw a contrast, have been tempted to suggest that earlier Theories of the Earth such as Burnet's were based primarily upon the textual evidence of Genesis. However hazardous, this assessment would be easier for someone like Lyell to make, of course, after standards of humanist scholarship had progressed beyond the seventeenth-century milieu in which Burnet wrote, and long after the demise of Cartesian natural philosophy (which provided Burnet's Theory with its natural philosophical matrix). And such a contrast would serve the "warfare of science vs. religion" rhetoric that followed the professionalization of geology, demoting (or in some cases, marginalizing) amateur divines to the status of local collectors, whose at best provincial field expertise severely restricted the legitimacy of any theoretical effort they might attempt.

Yet the assessment of textual evidence by Theorists of the Earth in their pursuit of a complete picture of the Earth's past is not primarily a question of the relations between science and religion.[136] Attempts to interpret it as such inevitably impose a historiographical frame of reference that is far too narrow. A science and religion filter excludes *prima facie*, for instance, the claims of seventeenth-century humanist scholarship in chronology, philology and antiquities, as well as textual traditions of meteorological and biblical commentary, all of which posed formidable knowledge claims of potential relevance to the formation and history of the Earth.

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[135]For instance, see the long concluding paragraph of "Nicholls, Conference with a Theist, 1698" on page 516.

[136]It is not enough like Lyell simply to assert that biblical interpretation curtailed scientific inquiry. Nor would it be insightful merely to argue the opposite, that the hexameral traditions encouraged scientific inquiry. Rather, leaving apologetics for both views aside, the more properly historiographical question has less to do with normative questions of current scientific or theological methodology than with the interpretative question of how the hexameral tradition shaped early Theories of the Earth and other endeavours which we recognize as significant for the emergence of geology. Brooke argues that boundaries between science and religion are difficult to conceptualize without anachronism: "To abstract both the 'science' and the 'religion' and then try to establish their mutual relationship can be highly artificial." John Hedley Brooke, *Science and Religion: Some Historical Perspectives*, Cambridge History of Science Series (Cambridge: Cambridge University Press, 1991), 11. To the degree this is so it becomes meaningless to hijack the historiography of science and religion to defend either one as prior to or superior to the other. The fundamental questions at issue with Theories of the Earth as a textual tradition are not first scientific and religious, but rhetorical and hermeneutical.

Rather, the broader historiographical issue is the use of textual evidence; *i.e.*, the manner in which textual traditions shaped inquiry and the cultivation of empirical evidence. So while *extra-biblical* evidence was most definitely not ignored by seventeenth and eighteenth century Theorists of the Earth, a transformation indeed occurred in the development of specific kinds of *extra-textual* evidence upon which Theorists and geologists primarily relied.

This transformation from a predominantly *textual* tradition into a set of largely *technical* disciplines therefore resists characterization as a "Baconian" transition from rhetorical argument to a reliance upon empirical demonstration. Rhetoric was not noticeably less utilized by Lyell and other geologists in the nineteenth century, and reports of empirical evidence, often in the form of virtual witnesses or visual representations with empirical referents, were not lacking in the texts of early Theorists (the Theories themselves called for and emphasized various kinds of experience and observation). Rather than a simple Baconian displacement of textual authority by direct experience, the transformation affected how empirical evidence was embodied in the texts by which it was authoritatively conveyed, and reflects the gradual emergence of technical disciplines, each comprised of mutually-acknowledged experts holding some degree of consensus regarding the specialized techniques of their investigative enterprise and the sort of problems which they were suited to address.

These questions are diffuse and unwieldy, and to explore them with respect to Theories of the Earth a more limited focus is needed. It is helpful to isolate one or two representative strands within Theories of the Earth that together disclose the character of Theories of the Earth as a textual tradition and at the same time illumine how temporal sensibilities were shaped within the tradition. Which textual tradition appropriated by Theorists of the Earth is most likely to reveal how the reading of texts shaped Theorists' visions of the past? Although any principle of selection is agonizing and potentially arbitrary, narrowing our focus to the appropriation by Theories of the Earth of just one representative textual tradition does not resolve the methodological difficulties. Clearly there is no single answer, no single textual strand uniquely responsible for the complex development of a historical sense of the Earth's past. Seventeenth-century antiquities and historical works have been studied with great insight by William Ashworth, Joseph Levine, and Rhoda Rappaport.[137] Traditions of cosmology, geography, providential theology, alchemy, mineralogy, and even the interpretation of ancient mythology, all played significant roles in particular Theories of the Earth, in many cases far overshadowing traditions of biblical commentary. Seneca's *Natural Questions* and Aristotle's *Meteorology* continued to be cited (often with favor) through the eighteenth century, and an adequate study of the significance of the meteorological tradition for Theories of the Earth would be as important as the consideration of any other textual tradition. Yet the text of Genesis has been selected for special attention not because it was the only ancient text with a continuous tradition of vigorous commentary of interest to Theorists of the Earth, but because it was taken seriously by people with greatly differing intellectual contexts, and over a long period of time it was widely regarded as the most authoritative for deciphering the history of the Earth. The Bible was like no other ancient text. It held a unique status, with a higher and longer-lasting authority than, say, Ovid, Aristotle, Seneca, Hermes, or ancient myths.

Authority is not a sufficient selection criterion, however, for authoritative texts may be obscure in their influence as well as their meaning. If intellectual history is the mental equivalent of trying to "nail jelly to the wall," then any attempt to trace the intellectual significance of such a culturally-pervasive text as the Bible is like trying to hold water in one's hands.[138] A still further narrowing of focus is necessary. Within the book of Genesis itself, the *hexameron*, or account of the creation week, has been selected. This should not be unexpected, for admi-

[137] Ashworth, "Sense of the Past"; Joseph M. Levine, *Dr. Woodward's Shield: History, Science, and Satire in Augustan England* (Berkeley: University of California Press, 1977); Rappaport, *When Geologists were Historians.*

[138] "Nailing jelly to the wall" is the phrase of William Hesseltine, cited by Francis Oakley, *Omnipotence, Covenant, and Order: An Excursion in the History of Ideas from Abelard to Leibniz* (Ithaca: Cornell University Press, 1984), 19.

rable studies of the account of Noah's Flood already exist, yet the significance of the deluge was arguably no greater than the creation week.[139] A vigorous tradition of hexameral commentary was intimately associated with Theories of the Earth, and Chapter 4, "Theories of the Earth and Visual Representations," illustrates the significance of the hexameral tradition for early modern natural knowledge. As will be seen, many natural philosophers drew up global and cosmic sections in part to depict how their views related to theoretical questions long discussed in commentaries on the creation week.

The hexameron by itself is still far too broad an inquiry. No adequate book-length general historical survey of hexameral interpretation exists.[140] Historical interpretations of the fourth day are touched upon by Howard J. Van Till, *The Fourth Day* (1986); other astronomical questions arising in the hexameron are surveyed by Stanley L. Jaki, *Genesis 1 Through the Ages* (1992). Historical interpretations of the second half of the third day provide a focus for Ernest C. Messenger, *Evolution and Theology: The Problem of Man's Origin* (1932).[141] In the

[139]The text of the hexameron according to the Geneva Bible, including its annotations, is provided alongside the Vulgate in the Appendix. The most important studies of Noah's deluge in seventeenth and eighteenth century thought are Rhoda Rappaport, "Geology and Orthodoxy: The Case of Noah's Flood in 18th-Century Thought," *British Journal for the History of Science* 11 (1978): 1–18; Don Cameron Allen, *The Legend of Noah* (Urbana: University of Illinois Press, 1949); and Davis A. Young, *The Biblical Flood: A Case Study of the Church's Response to Extrabiblical Evidence* (Grand Rapids: Eerdmans, 1995). Excerpts from Rappaport and Allen are reprinted in Alan Dundes, *The Flood Myth* (Berkeley: University of California Press, 1988). See also the comment on Bono in footnote 153. For earlier periods see Eugene S. McCartney, "Noah's Ark and the Flood: A Study in Patristic Literature and Modern Folklore," *Papers of the Michigan Academy of Science, Arts, and Letters* 18 (1932): 71–100; Richard W. Unger, *The Art of Medieval Technology: Images of Noah the Shipbuilder* (New Brunswick: Rutgers University Press, 1991); Lloyd R. Bailey, *Noah: The Person and the Story in History and Tradition*, Studies on Personalities of the Old Testament, ed. James L. Crenshaw (Columbia: University of South Carolina Press, 1989); Jack P. Lewis, *A Study of the Interpretation of Noah and the Flood in Jewish and Christian Literature* (Leiden: E. J. Brill, 1968). A recent illustrated overview is offered by Norman Cohn, *Noah's Flood: The Genesis Story in Western Thought* (New Haven: Yale University Press, 1996). In William Ryan and Walter Pitman, *Noah's Flood: The New Scientific Discoveries about the Event that Changed History* (New York: Touchstone, Published by Simon & Schuster, 1998), two well-known geologists offer perhaps the best-supported interpretation of flood legends at present, surveying geological, archaeological and linguistic evidence for a catastrophic flooding of inhabited settlements around a freshwater lake in the Black Sea basin around 5,600 BC, which occurred due to a breaching of the Bosporus and consequent rapid inflow of Mediterranean salt water. The book also includes a very readable overview of nineteenth-century interpretations of the Deluge, from William Buckland and Louis Agassiz to the early archaeological discoveries in the Middle East including the Epic of Gilgamesh.

[140]Important general studies include Arnold Williams, *The Common Expositor: An Account of the Commentaries on Genesis, 1527–1633* (Chapel Hill: University of North Carolina Press, 1948); Frank Egleston Robbins, "The Hexaemeral Literature: A Study of the Greek and Latin Commentaries on Genesis" (Ph.D. dissertation, University of Chicago, 1912); and Nicholas H. Steneck, *Science and Creation in the Middle Ages* (South Bend: Notre Dame University Press, 1976).

first two chapters of Part II a more precise focus within the hexameron for this study emerges because of the prominence of cosmic sections and global illustrations representing interpretations of the third day. Many Theorists explicitly related their global sections to the separation of the dry land and the seas on the third day. Rather than analyzing the texts by tracing the trajectories of isolated unit ideas selected on an arbitrary basis, the "reading" of visual illustrations is used in Part II to frame the textual interpretation by suggesting the significance of discourse on the third day. As a consequence, we will see that the account of the third day arguably had as much to do with the development of historical sensibilities for the Earth as any other textual locus, Seneca's conflagrations and Noah's flood included (although not necessarily in ways one might expect). These chapters also review some of the general questions raised regarding consonances and dissonances between practices of interpreting the "book of God's Works" and the "book of God's Word" as they affected the historical visions of Theorists of the Earth.[142]

In sum, this study selectively but not arbitrarily concentrates on the convergence of two early-modern textual traditions with Theories of the Earth:

- Visual illustrations of the Earth in the form of global sections and views;[143]
- Hexameral idiom, or the specific words, phrases, language, and conceptual framework of the first chapter of Genesis, particularly the third day.

Along with the textual tradition of Theories of the Earth (in which global sections and views were prominently deployed, often to illustrate hexameral idiom), all three of these textual traditions raise to prominence questions about how textual traditions were involved in the shap-

[141]Howard J. Van Till, *The Fourth Day* (Downer's Grove: InterVarsity Press, 1986); Stanley L. Jaki, *Genesis 1 Through the Ages* (London: Thomas More Press, distributed in the United States by the Wethersfield Institute, New York, 1992); Ernest C. Messenger, *Evolution and Theology: The Problem of Man's Origin* (New York: MacMillan, 1932).

[142]The two-books metaphor, medieval in origin, was used by Francis Bacon who argued against the alchemists for their disjunction; see next section, "Textual versus Technical Traditions."

[143]Why the visual tradition of global sections and views may be regarded as a textual tradition is explained in "Discovery and Demonstration through Nontechnical Diagrams," beginning on page 386, and why it provides a holistic and representative portrait of Theories of the Earth is argued in "Self-Portrait of the Tradition," beginning on page 397.

ing of empirical practices, the posing of particular kinds of questions, and the privileging of particular kinds of evidence. All three textual traditions were discursive, integrative, and able to travel widely across institutional, professional, scholarly, and cognitive boundaries. The scope of each of these three traditions is immense. No two of these three traditions were co-extensive, but they converged in the seventeenth century to a degree that global illustrations and hexameral idiom were often conflated with Theories of the Earth by contemporary and later observers.

In an important study of classical textual traditions, Anthony Grafton has shown how ancient geographical texts proved both resilient and adaptable in the face of unexpected discoveries in the New World:

> A revolution in the forms of knowledge and expression took place in early modern Europe. But it resulted as much from contradictions between and tensions within the texts as from their confrontation with external novelties. The ancient texts served as both tools and obstacles for the intellectual exploration of new worlds.[144]

According to Grafton, ancient texts were more complex than is usually acknowledged, and their meanings could change with remarkable facility:

> The texts provided European intellectuals not with a single grid that imposed a uniform order on all new information, but with a complex set of overlapping stencils, a rich and delicate set of patterns and contrivances. These produced diverse, provocative, ultimately revolutionary assemblies of new facts and images.[145]

Similarly, as will be shown below, internal tensions elucidated by the hexameral commentary tradition denied the possibility of any straightforward literal reading of Genesis. Luther began his commentary on Genesis with these cautionary words:

> The first chapter is written in the simplest language; yet it contains matters of the utmost importance and very difficult to understand. It was for this reason, as St. Jerome asserts, that among the Hebrews it was forbidden for anyone under thirty to read the chapter or to expound it for others.[146]

[144]Grafton, *New Worlds, Ancient Texts*, 6.
[145]Grafton, *New Worlds, Ancient Texts*, 58.

The text required interpretation, and its changing meanings served as both "tools and obstacles" for the intellectual exploration of the Earth's past. Moreover, the foundational use of Genesis did not determine any particular outcome; wholly different and mutually contradictory schemes were discerned in the text by different writers, or even by the same writer at different times, depending on the precise mix of extrabiblical considerations that were brought to bear as keys to interpretation. Yet this fluidity of meaning does not imply the sterility of a text whose use is merely ornamental or cosmetic: the nearly endless search for concordism with ancient texts significantly shaped the course of inquiry and the outlines of historical sensibilities.[147]

[146] Martin Luther, *Lectures on Genesis, Chapters 1–5*, ed. Jaroslav Pelikan and Daniel E. Poellot, vol. 1 of *Luther's Works*, 50 vols. (St. Louis: Concordia Publishing House, 1958), 3.

[147] In suggesting promising lines of inquiry for intellectual historians attempting to understand how historical actors imposed meaning on their experiences, Bouwsma comments that "the connections between a language and the perceptions of reality of those who speak it, as well as the significance of linguistic change, although often recognized in the abstract, have not yet seriously engaged historians." William J. Bouwsma, "From History of Ideas to History of Meaning," *Journal of Interdisciplinary History* 12 (1981): 290.

FIGURE 5. Francis Bacon, frontispiece, *Instauratio magna* (1620). HSCI.

Explanation. Bacon's often-reprinted frontispiece depicts ships sailing beyond the straights of Gibralter embodying the motto *Plus ultra*, thus conveying Bacon's confidence in the superior reach of modern discovery.

Ironically, given the epigraph at the head of this section, even Francis Bacon relied on ancient texts, and he did so even when condemning the idolatrous use of textual authority. Not only did Bacon believe in a pristine wisdom which it was the task of moderns following his program to recover but, as Grafton observes, the "most traditional of sanctions underpinned his command to throw off all tradition." Grafton points out that the famous title page of the *Great Instauration* (*Instauratio magna,* 1620), an emblem of modern accomplishment, is corroborated by a caption from an ancient text: "Many shall pass to and fro, and knowledge shall be increased" (Daniel 12.4). Grafton argues that "Textual authority still catalyzed the interaction among data even when the data no longer came from the texts."[148]

The first two chapters of Part II explore how a text such as Genesis catalyzed the search for meaningful data and affected their interpretation. By means of several case studies it is seen that, first, Genesis proved accommodating, capacious, and elastic in a textual tradition,

[148]Grafton, *New Worlds, Ancient Texts*, 217. Grafton's analysis of Bacon is found in pp. 197-217.

despite instances of inertia and rigidity in conventional interpretations. Second, reconciliation with the textual traditions surrounding Genesis often served as a prerequisite for the reception and dissemination of new natural knowledge. Indeed, Genesis proved difficult to read without the enlistment of some scheme of natural knowledge as a key to interpretation. Such enlistment, if widely adopted, counts as the "Assimilation" stage in Sabra's model of the transformation of traditions: the successful use of a natural philosophical key could allow the new scheme of natural knowledge—and the new discourse of Theories of the Earth—to participate in the cultural authority of the hexameron itself.[149] As a consequence, rhetorical strategies and the recruitment of audiences shaped both how texts were read and how they were written. Third, interpretations of Genesis were not merely ornamental rhetoric, but often played a substantive role in shaping the terms of questioning, influencing the idiom in which problems were formulated, directing empirical research, and providing criteria by which various possible lines of inquiry were either pursued as promising or rejected as unwarranted.

[149] The "appropriation model" of A. I. Sabra is discussed below; see Table 41, "Sabra's Appropriation Model for Scientific Traditions," on page 342.

§ 3-vi. Textual versus Technical Traditions

Theories of the Earth comprised a tradition of debate and argument by textual means, for the most part directed to a variety of expert readers who shared a common knowledge of well-known texts that were accessible without special technical expertise. Such texts included previous Theories of the Earth, contemporary travel literature, and other philosophical, biblical, and classical sources which were largely familiar to literate readers. To participate in the Theory of the Earth tradition was in part to engage a succession of texts published for a general or multi-disciplinary readership, albeit with an eye to making some of them obsolete or at least bringing them up to date by the introduction of some new line of crucial empirical evidence or some new theoretical insight or interpretative perspective. Thus the historiographical questions of greatest significance for understanding Theories of the Earth center neither upon the alleged simple Baconian displacement of textual authority by direct observation nor upon the relations between science and religion (see previous section), but rather upon problems of how texts were read and how the reading of texts helped to shape the ongoing tradition and the quest for improved natural knowledge of the Earth.

Textual traditions shape the practice of science more than is recognized. To return to the example of Francis Bacon, William Ashworth observes that a visual representation facing the *Plus ultra* frontispiece deployed the image of the natural philosopher not as a scientist within a separate non-bookish culture (as C.P. Snow would later characterize it), but as one who *writes* in texts what he *reads* from the book of nature.[150] The metaphor of the book of nature has received renewed historical attention because it provided significant motivation and clear sanction for natural inquiries that might otherwise have been spurned as vain curiosity. Moreover, it has been observed that the motivation supplied by the metaphor was religious in character and could be as powerful as the obligation to study scripture itself.[151] Francis Bacon's oft-quoted passage on the two books exemplifies the potent sanction for seeking natural knowledge which the metaphor provided early modern naturalists:

> Let no man, upon a weak conceit of sobriety or an ill-applied moderation, think or maintain that a man can search too far or be too well-studied in the book of God's word or in the book of God's works; divinity or philosophy; but rather let men endeavour an endless progress or proficience in both; only let men beware that they apply both to charity, and not to swelling; to use, and not to ostentation; and again, that they do not unwisely mingle or confound these learnings together.[152]

It is also critical to appreciate that as the two-books metaphor furnished a powerful sanction for natural inquiry it simultaneously implied that nature should be read like a text, and that natural phenomena should be collated and compared with knowledge from other texts, a fact which underscores the necessity of understanding the role of textual traditions in seventeenth-century natural knowledge. This implication of the metaphor has been recognized by

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[150]William B. Ashworth, Jr., "The Natural Philosopher at Work: The Transformation of an Image in Early Modern Science," paper presented at the Golden Jubilee Celebration of the University of Oklahoma's History of Science Program, March 24, 2000. The frontispiece appears in Francis Bacon, *Instauratio magna* (Londini: Apud Joannem Billium, typographum Regium, 1620); the portrait faces the frontispiece in Francis Bacon, *Of the Advancement and Proficience of Learning, or the Partitions of Sciences* (Oxford: Printed by Leon Lichfield, Printer to the University, for Rob Young and Ed Forrest, 1640). A classic expression of scientific culture as anti-bookish occurs in the description C. P. Snow offered his fellow humanists: "Remember, these are very intelligent men. Their culture is in many ways an exacting one. It doesn't contain much art, with the exception, an important exception, of music.... Books, very little, though perhaps not many would go so far as one hero, who perhaps I should admit was further down the scientific ladder than the people I've been talking about—who, when asked what books he read, replied firmly and confidently: 'Books? I prefer to use my books as tools.'" Charles Percy Snow, *The Two Cultures and the Scientific Revolution* (Cambridge: Cambridge University Press, 1959), 14.

[151]Brooke observes that seventeenth-century writers perceived an obligation to study the Book of God's Works as well as the Book of God's Word; John Hedley Brooke, *Science and Religion: Some Historical Perspectives,* Cambridge History of Science Series (Cambridge: Cambridge University Press, 1991), 22. In an extended analysis, Harrison comments that the medieval usage of the two-books metaphor "implied firstly, that nature was to be read, expounded, investigated; that those meticulous labours which had hitherto been expended on the methodical investigation of that other book could now be directed towards the natural world. Indeed, those who expounded the book of nature were to bring to their new subject the habits of mind and techniques which they had employed in the investigation of scripture. Equally importantly, this metaphor implied that the world, like scripture, was a locus of divine revelation, and potentially both a source of knowledge of God and a means by which mankind might be reconciled to him. Nature was thus a new authority, an alternative text, a doorway to the divine which could stand alongside the sacred page.... Study of the world took on a religious significance, and the exegesis of the book of nature became a vital concern." Peter Harrison, *The Bible, Protestantism, and the Rise of Natural Science* (Cambridge: Cambridge University Press, 1998), 45.

[152]Francis Bacon, *The Advancement of Learning,* Book I, in Brian Vickers, ed., *Francis Bacon: A Critical Edition of the Major Works,* The Oxford Authors, ed. Frank Kermode (Oxford: Oxford University Press, 1996), 126; *The Works of Francis Bacon,* ed. James Spedding, R. L. Ellis and D. D. Heath, 14 vols. (London, 1859–64), 3: 268.

James Bono, who shows in a remarkable study that the much-vaunted transition from studying words to studying things was "authorized by the narrative reworking of the very trope of the 'Book' [of Nature]."[153] Bono refutes the Baconian claim that in the seventeenth century an emerging scientific culture simply abandoned the bookish culture of exegetical and commentary traditions and abruptly replaced it with an altogether different approach:

> Most baldly put, scientific culture—at least in early modern Europe—does not represent a break from enchantment with the figure of the Book, nor from the authorizing presence of the Word. Rather, it represents the transformation of such enchantment and presence into new cultural practices that remain 'textual,' though no longer wedded to the exegetical and commentarial traditions of the old, bookish culture.[154]

Early modern natural philosophers staked out a variety of hermeneutical positions regarding the most appropriate means for interpreting the book of nature. On the one hand, at times the book of nature metaphor may reflect an optimistic sense of the book's perspicuity, or nature's intelligibility, as in Galileo's proclamation that the language of nature is mathematics which brings the essences of things into clear light of day:

> Philosophy is written in this grand book—I mean the universe—which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering about in a dark labyrinth.[155]

But on the other hand, the metaphor also hints at the possibility that the book of nature may be obscure, and the meaning of the text may remain as elusive as an Egyptian hieroglyph until

[153] James J. Bono, *Ficino to Descartes,* vol. 1 of *The Word of God and the Languages of Man: Interpreting Nature in Early Modern Science and Medicine,* 2 vols., Science and Literature, ed. George Levine (Madison: University of Wisconsin Press, 1995), 24; hereafter "Bono, *Ficino to Descartes.*" In this stimulating study Bono concentrates on Neoplatonic theories of language and master cultural narratives such as Adam naming the animals in the Garden of Eden and the confusion of tongues at the Tower of Babel.

[154] Bono, *Ficino to Descartes*, 5. Bono continues (p. 13): "the metaphor of the Book was foundational to both bookish and scientific cultures of the early modern period. Rather than an abrupt *rupture* dissociating the 'two cultures,' I contend that the transition between the two involves attempts to contain and negotiate new meanings that try to attach themselves to the metaphor of the Book...."

one acquires an adequate means of deciphering it. A paradigmatic example of the latter view is Robert Boyle's diffidence, arising from the belief that the text of nature (like scripture) is too complex to be contained in one view or comprehended all at once, that therefore interpretations of one particular locus must remain open to revision as they are reconciled with other cases, with the consequence that knowledge of sensible things is obtained only through an ongoing program of cautious experimentation.[156] The last clause in the passage quoted above by Francis Bacon—arguing in part against alchemists who mystically mingled esoteric religious symbolism with their chemical arts—suggests a position on the perspicuity-obscurity continuum closer to Boyle's than to Galileo's. In sum, the two-books metaphor functioned as a common currency, allowing the translation of the principal claims of different disciplinary or technical traditions into a primary and shared discourse.[157]

Most generally then, as the metaphor of the book of nature suggests, textual traditions facilitate the pursuit of natural knowledge across disciplinary divides. This observation leads

[155] *The Assayer*, translated in Stillman Drake, *The Controversy on the Comets of 1618* (Philadelphia: University of Pennsylvania Press, 1960), 183–184. Jean Dietz Moss argues that this well-known passage from *Il Saggiatore*, often cited as evidence of Galileo's Platonism, is best interpreted as an argument against textual authority. However, this point does not detract from the fact that Galileo argued against the peripatetics' epistemological pessimism on the basis of a textual metaphor implying that nature may and should be read as a text written in the language of geometry. See Jean Dietz Moss, *Novelties in the Heavens: Rhetoric and Science in the Copernican Controversy* (Chicago: University of Chicago Press, 1992), 247. Bono offers a perceptive analysis of this passage as a movement "from exegesis to deinscriptive hermeneutics," exploring how Galileo's use of the metaphor shifted the terms of debate from a comparison of the merits of texts written by Galileo vs. his scholastic opponents to a new context where scholastic texts are compared with the universe itself as a text even apart from the human act of reading or comprehending: "where earlier natural philosophers figured nature as a divine book whose meaning man must learn to interpret correctly, Galileo figures nature as an 'open' text that he can read directly, without the need for interpretation!" Bono, *From Ficino to Descartes*, 195. A classic discussion of early seventeenth-century epistemological optimism is Karl R. Popper, "On the Sources of Knowledge and of Ignorance," in *Conjectures and Refutations,* 5th ed. (London: Routledge and Kegan Paul, 1989), especially pp. 5–9.

[156] Sargent's succinct analysis of the deliberate and explicit coherence between Boyle's biblical hermeneutics and his experimental philosophy brilliantly illumines these issues; Rose-Mary Sargent, *The Diffident Naturalist: Robert Boyle and the Philosophy of Experiment,* Science and Its Conceptual Foundations, ed. David l. Hull (Chicago: University of Chicago Press, 1995), chapter 5, "Biblical Hermeneutics." Sargent writes (p. 111) that for Boyle: "Because the book of nature 'was written for man's instruction,' its complexity does not preclude our understanding it. But its complexity does require that our successful understanding of nature will depend upon knowledge of a vast number of particulars and upon our ability to reason correctly about the relations that hold between them. The world is a coherent whole, but we are not able to comprehend it all at once. Only by employing a method of proof that has the flexibility exhibited by moral demonstration will progress in our knowledge be assured.... For Boyle the experimental method was a means by which one could 'interpret' the book of nature." Cf. Robert Boyle, "Some Considerations Touching the Style of the Holy Scriptures," in *The Works of the Honourable Robert Boyle*, ed. Thomas Birch, 6 vols. (London, 1972), 2: 247–322.

to a distinction (or more accurately, a continuum) between textual and technical traditions (Table 7). In general, a textual tradition is more accessible to the reading public; a technical tradition can be understood only by a much more restricted audience. In the public forum of a textual tradition writers take greater pains to explain their underlying practices and evidential procedures; in a technical tradition expertise is tacitly assumed.

TABLE 7. Textual and Technical Traditions

Textual Traditions	Technical Traditions
Public forum	More restricted audience
Practices and evidences made remotely accessible to non-expert readers	Expertise tacitly assumed; outsiders excluded from access or understanding
Examples: •Textbooks, Popularizations •Interdisciplinary investigations •Disciplinary syntheses (if disparate subfields) •Theories of the Earth	Examples: •Disciplinary syntheses (if few subfields) •Alchemy, Mineralogy, Medical astrology, Mathematical astronomy, Chronology, Philology, Geology

Texts are important in technical traditions, and practices are important in textual traditions; the distinction rests on for whom the texts are written. A technical tradition depends upon a set of nonliterary practices, familiarity with which is tacitly assumed in its texts. The distinguishing feature of a technical tradition, whether of astronomy in the sixteenth century,[158] alchemy in the seventeenth century,[159] or of stratigraphy in the nineteenth cen-

[157]Bono comments: "The 'natural and experimental history' of Bacon, the probabilism of Mersenne's mathematical and observational methods and mechanism, the Cartesian 'mathesis, ou mathématique universelle,' and Boyle's 'experimental life' with its instrumental and literary technologies all constitute new practices incorporating new technologies for reading—and reconstructing—the divine Book. Each, of course, has its limits and its strengths. But all depended upon the central trope of the Book; all purported to read that Book. All were therefore authorized by the Word, access to whose 'meaning' legitimized their respective discursive practices." Bono, *Ficino to Descartes*, 6.

[158]Copernicus advised theologians not to prematurely denounce his work, since "Mathematics is for mathematicians." Commentaries on the Sphere of Sacrobosco constituted a textual tradition in medieval astronomy: Francis Johnson estimated at least 30 editions printed before 1501, and at least 200 editions printed between 1501 and 1600. Francis R. Johnson, "Astronomical Text-books in the Sixteenth Century," in *Science, Medicine, and History*, ed. E. Ashworth Underwood (Oxford: Oxford University Press, 1953), 2: 285–302. Lattis comments: "It is intriguing that the commentary on Sacrobosco's Sphere was so very long-lived. There are published editions as late as the middle of the seventeenth century. The first British Astronomer Royal, John Flamsteed, was, by his own account, first introduced to astronomy through a study of Sacrobosco's venerable Sphere. What sustained this remarkable popularity?" James M. Lattis, Between Copernicus and Galileo: *Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago: University of Chicago Press, 1994), 42.

tury,[160] is the degree of tacit, specialized expertise required of the reader—a point almost always lost when the origin of a technical tradition is cast as a Baconian displacement of rhetorical argument by empirical evidence (see previous section). Thus a technical tradition requires acknowledged experts who share consensual beliefs about specialized practices by which reliable knowledge is to be obtained, and technical works are written for those who employ those techniques.[161] In contrast, that Theories of the Earth were a textual rather than a technical tradition reflects both their textual methods of persuasion and their more general audience. That is, as a textual tradition Theories of the Earth were mobile, or remotely persuasive (one didn't have to be physically present), and they were relatively accessible to readers of diverse backgrounds across what would now be described as multiple disciplinary contexts

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[159]The interplay of textual and technical traditions throws some light on the thorny issues related to the simultaneous existence in the seventeenth century of technical alchemy and a textbook tradition in chemistry, in contrast to models of the didactic origins of chemistry emerging from an obscure and mystical technical alchemy; cf. Owen Hannaway, *The Chemists and the Word: The Didactic Origins of Chemistry* (Baltimore: Johns Hopkins University Press, 1975), and the criticisms of Hannaway by Lawrence M. Principe, *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton: Princeton University Press, 1998), 59, who documents that many of the textbook writers (including Boyle) remained practicing alchemists, and that the criticisms in Boyle's *Skeptical Chymist* were directed toward writers of textbooks and not just of mystical works.

[160]What I am referring to as a technical tradition is magisterially interpreted for the case of early nineteenth-century geology in Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985).

[161]This description of a technical tradition synthesizes aspects of Polanyi's philosophy of science with a rhetorical interpretation of the public spheres literature in the sociology of science. On tacit knowing in science see the second part of Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1962), Michael Polanyi, *The Tacit Dimension* (Garden City, NY: Doubleday and Company, 1966), and the essays in the second and third parts of Michael Polanyi, *Knowing and Being,* ed. Marjorie Grene (Chicago: University of Chicago Press, 1969). The specialized preparation underlying a technical tradition is emphasized by the literature on spheres of discourse, as Taylor explains: "the technical sphere is taken as any specialized discourse community in which mastery of a particular body of knowledge is presupposed." Charles Alan Taylor, *Defining Science: A Rhetoric of Demarcation,* Rhetoric of the Human Sciences (Madison: University of Wisconsin Press, 1996), 124; cf. footnote 113 on page 59. To avoid possible confusion, note that Mertonian sociologists and others sometimes refer to science as a consensual form of public knowledge, a formulation which at first appears to contradict (and to exactly reverse) my contrast between a "technical tradition" and the "public forum" of a "textual tradition." For example, John Ziman characterizes the conventions of science as "dominated by a single principle—their goal is the establishment and extension of a free intellectual consensus." Ideally, then, Ziman hopes for consensus of natural knowledge shared in the public forum. But immediately Ziman acknowledges a difficulty: "In the first place, we find that we cannot define the community over which the consensus is to be established, except rather narrowly as 'those educated and expert in the field.'" Thus Ziman concedes that science as public consensual knowledge practically applies only within a technical tradition. In my usage, then, it is a technical tradition and not a public textual tradition that more closely resembles such characterizations of science as a consensual enterprise of public knowledge. John M. Ziman, *Public Knowledge: An Essay Concerning the Social Dimension of Science* (Cambridge: Cambridge University Press, 1968), 145, 146. The Mertonian ethos of science is described on page 321ff.

(including the full spectrum of natural philosophy and natural history as well as theology, mineralogy, and classical learning).[162]

Nothing stated so far implies that a textual tradition is the only kind of public forum; many other traditions meet the same criteria of public access and the contesting of private expertise based on pragmatic rules of discourse. A public forum is well-described by William James as a corridor running through a hotel:

> Innumerable chambers open out of it. In one you may find a man writing an atheistic volume; in the next someone on his knees praying for faith and strength; in the third a chemist investigating a body's properties. In a fourth a system of idealistic metaphysics is being excogitated; in a fifth the impossibility of metaphysics is being proved. But they all own the corridor, and all must pass through it if they want a practicable way of getting into or out of their respective rooms.[163]

Many institutions are "public corridors" precisely analogous to textual traditions; without imposing pragmatism as a system of philosophy it may be noted that James' description aptly describes the provisional, methodological pragmatism of pluralistic discourse in a modern multi-university. In political philosophy, to take another example, Richard John Neuhaus

[162]The textual vs. technical distinction accords with Rappaport's account of how natural knowledge of the Earth became differentiated from traditions of historical scholarship by the late eighteenth century (cf. Rappaport, *When Geologists were Historians*), and it generalizes this transformation to comprehend other textual traditions of natural knowledge such as meteorology and hexameral commentary. A textual tradition is addressed to practitioners from multiple technical traditions; this is why some interdisciplinary syntheses might be considered as a relatively textual tradition if the subfields are disparate. To identify a relatively-textual tradition one looks for participants from multiple technical contexts. That the distinction is relative rather than absolute allows for the regarding of a literary tradition based on technical books which may be remotely practiced as a technical tradition even though it is intermediate, and relatively more textual than the same tradition would be if it later achieved enough practitioners in proximity to establish a network of collaborative projects and training methods. Peter Barker describes such a distinction: "Although it appears natural to refer to both medical astrologers and perspectivist natural philosophers as working within a tradition, the term means different things in the two cases. In one case, a tradition [an extreme technical tradition] embodies a continuous group of practitioners in active contact with one another, who recruit and train new members and collectively define a background for the research of individual members. Medical astrology was clearly such a tradition from the twelfth century through the sixteenth. By contrast, before the sixteenth century perspectivism was a literary tradition, or at least a tradition based on books. Its practitioners were dispersed, geographically and temporally. Although they regarded themselves as practitioners of a definable tradition, the main connections between them were written works on optics that each regarded as a common basis and to which each added. During the sixteenth century the perspectivists became a tradition in the richer sense, although books remained an important mode of communication." Peter Barker, "Understanding Change and Continuity," in *Tradition, Transmission, Transformation*, ed. F. Jamil Ragep and Sally P. Ragep with Steven Livesey (Leiden: Brill, 1996), 537.

[163]William James, "What Pragmatism Means," in William James, *Pragmatism, A New Name for Some Old Ways of Thinking, and The Meaning of Truth, A Sequel to Pragmatism* (Cambridge: Harvard University Press, 1975,1978), 32.

describes the participatory government of classical liberalism as a "naked public square" where citizens with diverse assumptions and competing allegiances come together to seek common ground on the basis of arguments accessible to all.[164] Like many institutions, textual traditions are public corridors and public squares, connecting various technical traditions like rooms in the hotel.

This distinction between textual traditions and technical traditions replaces the common dichotomy between speculative genres and empirical traditions. This dichotomy is flawed because, on the one hand, technical traditions like mathematics may be abstracted from nearly all empirical content. On the other hand, a textual tradition may convey empirical information as in the case of introductory science textbooks, popularizations, disciplinary syntheses, and interdisciplinary investigations. Controversies—often taken as manifest proof of speculative indulgence—may arise in textual traditions not due to an absence of empirical content but because of the collision of diverse technical orientations. Modern science is not far different in this respect; for example, in her analysis of patterns of citation in recent asteroid-impact controversies, Elisabeth Clemens found that the "debate has been carried out in front of a general scientific audience" through institutions of general science such as the non-specialized journals *Nature* and *Science*. Clemens concludes that "to the extent that a debate develops within such arenas, it is particularly likely to encounter clashes of assumptions and taken-for-granted knowledge that remain implicit in more narrowly-circumscribed efforts."[165]

To frame the distinction between textual and technical traditions improves upon the distinction between internalist and externalist perspectives. It preserves the recognition that internalist activities still enter James' corridor of public discourse and participate in the public

[164]Richard John Neuhaus, *The Naked Public Square: Religion & Democracy in America* (Grand Rapids: William B. Eerdmans, 1986).

[165]Elisabeth S. Clemens, "The Impact Hypothesis and Popular Science: Conditions and Consequences of Interdisciplinary Debate," in *The Mass-Extinction Debates: How Science Works in a Crisis,* ed. William Glen (Stanford: Stanford University Press, 1994), 106; hereafter "Clemens, 'Impact Hypothesis.'

square. In some philosophies of science, the distinction between the context of discovery and the context of justification parallels the internalist-externalist distinction, so that external factors are allowed to play a role in the context of discovery but only internalist factors are to be invoked in the context of justification. The context of justification is then taken to legitimate an historian's exclusive focus upon professional publications, which is then (perhaps circularly) taken as evidence for the demarcation of scientific argument from external considerations. And if such sanitized professional publications do not exist, then the research program may be dismissed as protoscientific. For example, these assumptions underlie Helge Kragh's survey of the controversy surrounding the steady-state and big bang theories in the mid-twentieth century,[166] and are tacitly shared by those who assert that cosmology first became a true science with the observational evidence for the big bang theory.[167] Yet technical traditions are not abstracted and insulated from textual traditions, and to characterize textual traditions as proto-science in any straightforward sense merely because they lack consensus, ruling paradigms, or a scientific ethos would be as absurd as to disparage the hotel corridor for not being a room furnished with a bed and shower.[168]

[166]One paragraph from Kragh's epilogue clearly reveals these assumptions at work: "I have concluded that this element ["non-scientific" perspectives] was more noisy than significant in the controversy, and that practically all the scientists involved were careful to distinguish between scientific and non-scientific arguments. In particular, the latter kind of argument did not, or at most very rarely, appear in the professional journals, where the controversy was presented as a fairly standard scientific debate. Its subject matter was grander and more awesome, but from a methodological point of view the controversy between two theories of the universe did not differ fundamentally from other, more mundane scientific disagreements. The broader philosophical and religious considerations definitely influenced the dispute, but mainly in shaping (some of) the contestants' preferences and not in the context of justification." This seems particularly at odds with Kragh's own earlier discussion of the ideological and philosophical commitments of various contestants which were expressed mainly in publications that were more public than technical (with the notable exception of Gamow's 1952 paper in the *Physical Review* introduced by a lengthy quotation from Pope Pius XII). Helge Kragh, *Cosmology and Controversy: The Historical Development of Two Theories of the Universe* (Princeton: Princeton University Press, 1996), 390, 256. Hereafter, Kragh, *Cosmology and Controversy.* For a sample of the ongoing theological and philosophical discussion see William Lane Craig and Quentin Smith, *Theism, Atheism and Big Bang Cosmology* (Oxford: Clarendon Press, 1993).

[167]"The new theory [steady-state theory], and the controversy that followed, helped cosmologists transform cosmology from a protoscience to a mature science." Kragh, *Cosmology and Controversy*, 392. Kragh repeatedly asserts this thesis, a boundary-drawing mantra then-as-now championed by proponents of the big bang, despite historical documentation that "none of the observations, either separately or collectively, were able to settle the controversy definitively. In particular, the discovery of the cosmic microwave background, although admittedly of very great importance, was not quite the crucial experiment it has often been claimed to be." Kragh, *Cosmology and Controversy*, 373.

Additionally, to frame the distinction between textual and technical traditions is more helpful than to distinguish between science proper, on the one hand, and an unsorted morass of popularizations, folk science and pseudoscience on the other.[169] The question of popularization immediately raises problems of audience, particularly the relations between Theories of the Earth and female readers. The analysis of Theories of the Earth and gender issues has not even begun, but recent work on texts intended in part for female readers such as Erasmus Darwin's *Botanic Garden* or Fontenelle's *Conversations on the Plurality of Worlds* (to cite a work from a sister textual tradition) may provide helpful starting points.[170] It is not possible here to comment adequately on these issues, but from the start it may be noted that Theories of the Earth from Descartes to Cuvier were significantly different in their textual character from many of their textbook, encyclopedia, and even folk-science offspring. It would be a serious mistake to restrict consideration of gender and Theories of the Earth merely to the questions of popularization, textbooks, and folk science, but the survival of Theories of the Earth in nineteenth-century women's textbooks after it had ceased to be a respectable professional endeavor merits special study. At times textbook traditions could spin off folk science such as Mary Salter's idiosyncratic theory of the Earth, published in 1907 despite the ridicule of professional geologists.[171] Similar processes of differentiation of Theories of the Earth into popular folk science occurred with movements as diverse as the scriptural geologists discussed in the previous section, late nineteenth- and twentieth-century hollow-Earthers, Velikovsky and his followers, Flood Geology, and advocates of new mystical movements.[172] Describing Theories of the Earth as a textual tradition rather than a more restricted technical discourse

[168]The points made in this paragraph are extended in "Controversy and the Rhetoric of Demarcation," beginning on page 307.

[169]For remarks on Theories of the Earth and psuedoscience see "Whiston and Pseudoscience," beginning on page 296.

[170]The paucity of gender studies relating to Theories of the Earth is evident from a perusal of Marilyn Bailey Ogilvie (with Kerry Lynne Meek), *Women and Science: An Annotated Bibliography*, Garland Reference Library of Social Science, vol. 859 (New York: Garland, 1996). On Darwin see Janet Browne, "Botany for Gentlemen: Erasmus Darwin and *The Loves of the Plants*," *Isis* 80 (1989): 593–621; and below, "Erasmus Darwin's Botanic Garden," beginning on page 674.

enables one to avoid attributing to it as a whole the marginal character of these folk-science vestiges. Textual traditions may facilitate and encompass textbooks and folk-science, but they are not reduced to these genres.

It is also possible to misconstrue Theories of the Earth as popular science in the sense of works which disseminate leading-edge science to a lay audience. In this regard one might think again of Erasmus Darwin's *Botanic Garden* or Gadroys' textbook explanation of Descartes' natural philosophy, Whiston's explanations of Newtonianism, and Robert Chambers' synthesis of early nineteenth-century theories of cosmological development and biological transformism. However, none of these are adequately characterized as top-down simplifications.[173] Although many became popular (or notorious) texts, most Theories of the Earth were intended as contributions to natural knowledge; this differs from simply translating frontier science into lay terms for the sake of informing the general public. Their textual character facilitated their engagement with multiple discourses, and writers often positioned

[171]Mary Salter, *A New System of Geology, With Archaeological Proofs of the Destruction of the World by Water and Fire* (London: Simpkin, Marshall, Hamilton, Kent & Co., 1907). Salter's Theory interpreted Earth history from its origin to the present according to a process of radioactive transmutation based on archeological inscriptions: "The history of the evolution of the universe is to be read on the two stones known as H.V. and J. III. They are the Siriadic pillars and contain the lore of the ancients, including Bible history." In her preface, Salter related that "The discovery that sand beds are the remains of primeval chaos was announced to the Geological Survey in person in May, 1904, but the idea was ridiculed." A note in the author's hand inserted (unbound) in the copy of the University of Oklahoma History of Science Collections protests how her radioactive theory of the Earth had been pirated by professionals and largely vindicated since its publication. On the obvious problems that arise when consideration of women's roles in early modern natural knowledge is limited to popularization see, for example, the "obligatory amateurs" described by Ogilvie; Marilyn Bailey Ogilvie, "Obligatory Amateurs: Annie Maunder (1868–1947) and British Women Astronomers at the Dawn of Professional Astronomy," *British Journal for the History of Science* 33 (2000): 67–84.

[172]For the scriptural geologists see "Natural Knowledge and Textual Traditions," beginning on page 66. On hollow-Earthers see "Magnetic Theories of the Earth," beginning on page 631. Velikovsky and Flood Geology are briefly discussed in "Whiston and Pseudoscience," beginning on page 296. More recently, Thomas Frick, ed., *The Sacred Theory of the Earth*, *Io*, no. 36 (Berkeley: North Atlantic Books, 1986), consists of an anthology of essays introduced as a branch of holistic mysticism called geomancy, in which "one must simply learn to *see* what the earth, as a living being, has to say." Frick's preface is followed by Burnet's frontispiece, printed without attribution.

[173]For a critique of this top-down conception of popularization see Stephen Hilgartner, "The Dominant View of Popularization: Conceptual Problems, Political Uses," *Social Studies of Science* 20 (1990): 519–539. See the articles in a thematic issue of *History of Science* devoted to popular science, including Roger Cooter and S. Pumfrey, "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture," *History of Science* 32 (1994): 237–267. On Gadroys see "Cartesian Cosmogonies," beginning on page 557; the instructive example of Chambers' *Vestiges of the Natural History of Creation* is briefly discussed in "Whiston and Pseudoscience," beginning on page 296; Whiston's Theory is considered at length in "A Newtonian Cosmogony: Whiston's Hexameral Theory," beginning on page 584.

themselves as experts addressing other experts who needed to be persuaded but whose expertise lay in different or more specialized areas. This aim is evident, for example, in the case of William Henry Fitton's review of Charles Lyell's *Elements of Geology* in 1839. Writing in the *Edinburgh Review* to readers for whom the Theory of the Earth remained a legitimate endeavor, Fitton characterized Lyell's work as a Theory of the Earth building upon the foundation laid by Hutton (indeed, one chief aim of Fitton's essay was to set the record straight on behalf of his fellow Scotsman and to compensate for Lyell's insufficient acknowledgment of his debt to Hutton). In his opening paragraph Fitton disabused his readers of any suspicion that Lyell's *Elements* was a work of popularization—despite its nature as a textbook conveying a Theory of the Earth:

> It is worthy of Mr. Lyell's reputation, but very different from what we had expected; for, having been mentioned in the advertisements as intended 'for beginners,' we had looked for something of a very plain and rudimentary description—a treatise, in short, that would have rendered the subject inviting by simplicity of style and illustration, and could have been read with ease and satisfaction by a well-educated woman.[174]

Fitton's characterization of popular works as texts written for well-educated women reinforces the need to study further the relations of gender issues and Theories of the Earth. However, with respect to popularization it reflects the fact that most Theorists (like Lyell and Fitton) believed they were going beyond the core knowledge which we might now view them as popularizing to make original contributions in their own right. As Ludwik Fleck observed, "Even the most specialized expert owes to [popular science] many concepts, many comparisons, and even his general viewpoint."[175] On any expert-to-public continuum, specialists from neighboring disciplines may be found in varying positions: no one is a specialist in every field;

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[174][William Henry Fitton], "Lyell's *Elements of Geology*, Huttonian Theory of the Earth," *Edinburgh Review* 69 (1839): 406.

[175]Ludwik Fleck, *Genesis and Development of a Scientific Fact,* trans. Fred Bradley and Thaddeus J. Trenn, ed. Thaddeus J. Trenn and Robert K. Merton, foreward by Thomas S. Kuhn (Chicago: University of Chicago Press, 1979), 112. Fleck offers a sustained discussion of popular and other forms of communication among scientists.

every specialist relies upon textual traditions for general knowledge, even within his or her own discipline. A striking contemporary example of this process in action is again provided by Clemens who notes that "with respect to issues outside their disciplinary specialty, active researchers in the United States are not all that different from the rest of the highly educated audience for science coverage published in the *[New York] Times*."[176] Clemens goes even further, suggesting that a bottom-to-top role of popular science more accurately applies to the impact controversies than a top-to-bottom popularization. That is, in a bottom-to-top reversal of the usual popularization model, the public education goals of natural history museums with their large specimens—the "dinosaurs" of popular science—shaped patterns of interest, the formulation of questions, and the forging of links between scientific disciplines.[177] Clemens' demonstration of the persistence of popular science ("the tenacity of the dinosaur connection"[178]) within the core of disciplinary research agendas in the impact controversies is directly analogous to the use of hexameral idiom and other familiar tropes in the multi-contextual discourse of Theories of the Earth. Thus Theories of the Earth resist description as works of popularization despite their degree of public interest and appropriation of popular science.

[176]Clemens, "The Impact Hypothesis," 100. Clemens writes (p. 98): "The universalistic label of 'scientist' obscures the mix of expert science, textbook science, and popular science that informs the thinking of any researcher. Consequently, conflict can arise, because the boundary between expertise and other knowledge about science is unclear."

[177]Clemens explains: "patterns of interest established outside the disciplinary frameworks of the sciences can have profound consequences in forging links among those disciplines. The long-standing popular fascination with dinosaurs provided a context within which both the general public and research scientists from a wide variety of disciplines became aware of a limited set of highly stylized questions concerning the history of extinction.... The scope and speed with which interest in the impact hypothesis spread cannot be understood apart from the fact that many people already believed that the question of how the dinosaurs died was both answerable and worth answering. Furthermore, distinct advantages flow from addressing questions widely perceived as significant. The effort that some researchers put into gaining acceptance for their work underscores the importance of this widespread public acceptance of the significance of a line of inquiry." Clemens, "The Impact Hypothesis," 103. Clemens' study documents how "the death of the dinosaurs" was rejected as a non-problem by many paleontological investigators of the KT boundary, with the result that they perceived some researchers as trying to explain an event that did not occur (p. 97). See also footnote 128 on page 330.

[178]Clemens, "The Impact Hypothesis," 97.

If textual traditions, therefore, are not adequately characterized as a speculative instead of an empirical genre, nor as an externalist context superfluous to the content of science, nor simply as textbooks, popularizations, proto-science or folk science, then what remains? On a fundamental level the presence of textual traditions in natural knowledge offers some important clues to processes underlying interdisciplinary investigations and the emergence of new disciplines. Like institutions, textual traditions provide continuity while accommodating and facilitating change. First, like institutions, texts help consolidate new disciplines, providing a common identity that is broader than the narrow identity of common experimental pathways or specialized core research programs. This is instanced in recent science, for despite a rhetorically-significant relative absence of references to books in journal literature, Bruce Lewenstein points out that the post-war years have seen an exponential rise in scientific books as well as journals. Lewenstein argues that books form an important aspect of recent scientific culture, observing that the abundance of conference proceedings, *Festschriften*, and frequently-handled reference works belies any suggestion that books serve scientists merely as secondary texts or popularizations. Besides the actual content of specific landmark works, Lewenstein explores how the shared reading of books forms common bonds, creates lively discourse, and defines particular scientific communities. As an historian of recent science Lewenstein attends to how scientists' use of books reflects their paradigmatic experiences, reveals interesting aspects of their daily practice, and shapes their social relations with various publics including other scientific communities.[179]

Second, texts reshape disciplinary alliances. Star and Griesemer's study of "boundary objects" in the construction of the Berkeley natural history museum is helpful on this point. They defined boundary objects as

[179]Bruce V. Lewenstein, "How Books Have Kept Science Alive Since World War II," paper presented at the Golden Jubilee Celebration of the University of Oklahoma's History of Science Program, March 24, 2000. Contrast the description of scientific culture by C.P. Snow in footnote 150 on page 80.

> objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds.[180]

The boundary objects analyzed by Star and Griesemer include animal species and their habitats, and the climate and terrain of California. Yet by their definition texts may also become boundary objects. In a concrete sense a particular Theory of the Earth may travel across various disciplinary contexts; in an abstract sense the discourse of "the Theory of the Earth" may be pursued "across intersecting social worlds." Theories of the Earth may also *contain* boundary objects "weakly structured in common use, and... strongly structured in individual site use," such as the two-books metaphor, hexameral idiom, and global illustrations.[181] Joan Fujimura includes boundary objects within her larger category of "standardized packages," or combinations of theories and techniques, which move together across worlds and into other social contexts. Standardized packages facilitate the stabilization of new techniques and disciplinary identities in a process that seems remarkably applicable to the outgrowth and dissemination of geognostic theories and fieldwork, described by Laudan as the Wernerian "adaptive radiation."[182]

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[180]Susan Leigh Star and James R. Griesemer, "Institutional Ecology, 'Translations,' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science* 19 (1989): 393.

[181]Bono's description (in a different context) conveys a sense of how hexameral idiom or particular Theories of the Earth might function as boundary objects: "While the focus on the text remained a constant and the full array of technologies of reading constituted a common resource, the interpretive strategies and specific hermeneutical practices deployed by the actors in this bookish culture were responsive to local variation." Bono, *Ficino to Descartes,* 12.

[182]Joan H. Fujimura, "Crafting Science: Standardized Packages, Boundary Objects, and 'Translation'," in *Science as Practice and Culture,* ed. Andrew Pickering, 168–211 (Chicago: University of Chicago Press, 1992), 168–211. On Werner, geognosy, the Wernerian adaptive radiation, and their relationship to Theories of the Earth see "Geognosy and the Wernerian Adaptive Radiation," beginning on page 116.

Both boundary objects and standardized packages serve as interfaces between multiple contexts and facilitate reciprocal translations. The degree to which boundary objects are contracted into piecemeal investigations or expanded into larger contexts often depends on the audience being addressed, as rhetorical needs shape not only presentation but also content and the generation of natural knowledge. Peter Dear summarizes a recent collection of studies on the significance of texts in science as sharing four common themes:

- The role of genres in perpetuating, changing, or subverting scientific research programs.
- The role of genres in defining disciplinary boundaries.
- The role of scientific texts in embodying the cognitive assumptions or social structure of the sciences to which they belong.
- The ways in which literary forms can direct the cognitive content of a science through constraining problem choice or through requiring (via their own disciplinary entrenchment) particular kinds of theoretical and experimental formulation.[183]

Each of these themes applies to Theories of the Earth as a textual tradition and to the hexameral idiom which Theories appropriated.

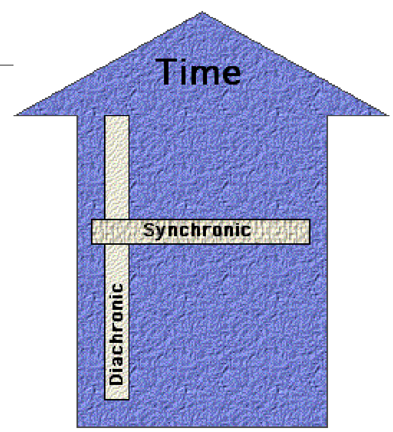


FIGURE 6. Fabric of Time: Diachronic continuities vs. Synchronic contexts.

Long-term diachronic surveys of the history of science have largely been abandoned by historians of science in favor of local studies of synchronic contexts. This move in large part results from the loss of belief in older Grand Narratives such as the Ascent of Man or the Scientific Revolu-

[183]Peter Dear, ed., *The Literary Structure of Scientific Argument: Historical Studies* (Philadelphia: University of Pennsylvania Press, 1991), 5. The role of textual traditions in the generation of natural knowledge is being given increased attention in current history of science with the emergence of the rhetoric of science as a new field of science studies. Seminal works in the rhetoric of science include Lawrence J. Prelli, *A Rhetoric of Science: Inventing Scientific Discourse* (Columbia: University of South Carolina Press, 1989); Alan G. Gross, *The Rhetoric of Science* (Cambridge: Harvard University Press, 1990); Greg Myers, *Writing Biology: Texts in the Social Construction of Scientific Knowledge* (Madison: University of Wisconsin Press, 1990); and Marcello Pera and William R. Shea, eds., *Persuading Science: The Art of Scientific Rhetoric* (Canton, Mass.: Science History Publications, 1991).

tion. The assumptions underlying these older narratives included the cumulative growth of scientific knowledge, the timeless boundaries of retroactively projected disciplines, the existence of an essential methodology of science, and the unity of science. Yet given the absence of accepted diachronic perspectives historians face an unresolved dilemma, for any synchronic study is framed according to some kind of diachronic perspective—even if that perspective is merely implicit or poorly examined. As we shall see in Chapter 3, sweeping attitudes toward Theories of the Earth too often still resemble the older grand narratives and, not surprisingly, rest in part on similar assumptions. Yet when concepts such as boundary objects are applied to textual traditions, diachronic study becomes possible without assuming an inherent unity of discourse. Such diachronic perspectives are necessary if we are better to understand the dynamics of a collective textual tradition such as Theories of the Earth which contingently developed among diverse local circumstances subject to multiple interpretations and uses.

Theories of the Earth and hexameral commentaries are an especially interesting example of textual traditions, however, because they were not mere ordinary textual traditions. They each go beyond the basic description summarized in Table 7, just as the two-books metaphor reveals a further dimension of the cultural significance of texts compared with the use of texts in recent science as illuminated by Clemens and Lewenstein. Both Theories of the Earth and the tradition of hexameral commentaries were nourished in exceptionally favorable circumstances due to textual habits instilled by Renaissance humanism. Renaissance textual habits fostered an emphasis on the collation and comparison of texts, privileged textual evidence, and sought literal interpretations of myths, sage remarks, and biblical texts. Sometimes humanist sensibilities were associated with *prisca sapientia* textual traditions in order to decode accepted riddles of past natural knowledge. Sometimes they were associated with the tools of technical chronology, archaeology or philology in order to reconstruct by modern ingenuity an unsuspected and utterly different human past.

In *Defenders of the Text* and other studies Anthony Grafton has shown how remarkably long-lived humanist scholarship was, even with respect to the natural sciences. Textual scholarship provided resources that stimulated and shaped the investigation of geological phenomena, a point recently elucidated by Rhoda Rappaport's *When Geologists were Historians*. Early Theories of the Earth were based upon scholastic traditions in meteorology, hexameral commentary, and physics, conjoined with movements for the reform of learning such as alchemy and humanist study of ancient texts, particularly mythology and the classics. Many scholars have shown how the reading of mythology, chronology, and classical literature influenced seventeenth- through nineteenth-century actors as diverse as Robert Hooke, Desmarest, Werner, Cuvier, Buckland, and Geikie. Readers of Theories of the Earth were familiar with Aristotle's *Meteorology*, Plato's *Phaedo* and *Timaeus*, Seneca's *Natural Questions*, Pliny's *Natural History*, Ovid's *Metamorphoses*, Strabo's *Geography*, Lucretius' *On the Nature of Things*, Cicero's *On the Nature of the Gods*, and Plutarch's *The Face of the Moon*, among others. Because of the breadth of potentially-relevant textual sources, readers of Theories of the Earth were habituated by humanist scholarship to privilege textual argument and to pay close attention to the critical evaluation of texts.[184]

The nineteenth-century decline of Theories of the Earth as a textual tradition and concomitant professionalization of geology reflects a transformation from a predominantly textual tradition to a largely technical discipline. The transformation from a predominantly textual tradition to a new configuration of technical disciplines was neither sudden nor dis-

[184]For Hooke see Kirsten Birkett and David Oldroyd, "Robert Hooke, Physico-Mythology, Knowledge of the World of the Ancients and Knowledge of the Ancient World," in *The Uses of Antiquity: The Scientific Revolution and the Classical Tradition,* ed. Stephen Gaukroger, 145–170. Australasian Studies in History and Philosophy of Science, ed. R. W. Home, no. 10 (Dordrecht: Kluwer Academic Publishers, 1991). For Desmarest see Kenneth L. Taylor, "La Genèse d'un Naturaliste: Desmarest, La Lecture et la Nature," in *De la Géologie à Son Histoire,* ed. Gabriel Gohau (Paris: Comité des Travaux Historiques et Scientifiques, 1997), 61–74. For Werner see Alexander M. Ospovat, "The Importance of Regional Geology in the Geological Theories of Abraham Gottlob Werner: A Contrary Opinion," *Annals of Science* 37 (1980): 433–440. For Buckland see Nicolaas A. Rupke, *The Great Chain of History: William Buckland and the English School of Geology (1814–1849)* (Oxford: Oxford University Press, 1983). For Geikie see David R. Oldroyd, "Sir Archibald Geikie (1835–1924), Geologist, Romantic Aesthete, and Historian of Geology: The Problem of Whig Historiography of Science," *Annals of Science* 37 (1980): 441–462.

crete, for meteorological, mineralogical, cosmological and other extra-textual evidence played critical roles in Theories of the Earth before 1800, and textual evidence continued to figure prominently in geological works after 1800 (as is evident from a perusal of the major works of Cuvier, Buckland, Lyell and Suess, for example). Actors contested which types of evidence should be privileged for which sorts of questions, thereby contributing to the eventual differentiation of distinct disciplines such as mineralogy, geology, cosmology and planetary physics in the eighteenth and nineteenth centuries. The decline of the textual tradition of Theories of the Earth as they were transformed into various technical traditions parallels and reflects the broader eighteenth-century differentiation of natural philosophy and natural history into multiple disciplinary fields of inquiry, considered by Thomas Hankins to be the most important contribution of the Enlightenment to the development of science.[185]

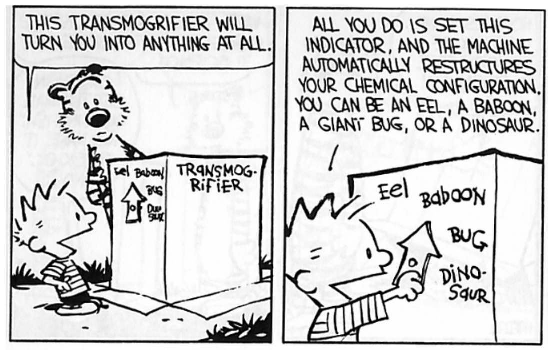
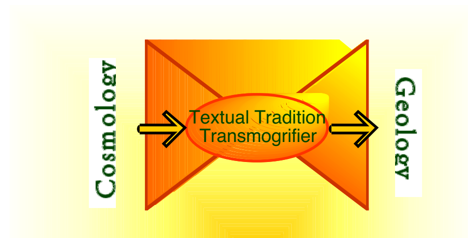
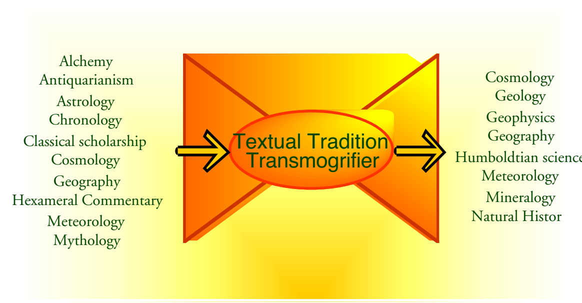
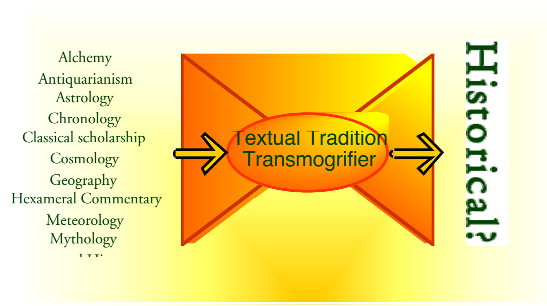
Thus as we conclude this section, “What were Theories of the Earth? A Clarification of Terms,” beginning on page 44, we recapitulate points made earlier in “Theories and Disciplines,” beginning on page 45, where we began to construct an alternative perspective of Theories of the Earth as a textual tradition. There it was said that Theories of the Earth were not a discipline, but a multi-contextual discourse. Theories of the Earth explored divides between pre-modern disciplines, forging alliances which no longer exist between various disciplines, some of which no longer exist, thereby establishing base camps or meeting places for divergent contextual discourses. The fluidity of mediating textual traditions facilitated the reconfigura-

[185]“The same difficulties arise in all parts of science. Chemistry was practiced largely by medical doctors, who saw it as part of their field. Because it included the study of the mineral kingdom, chemistry overlapped with natural history, the science that described and classified all forms of nature.... Chemistry also blended indistinguishably into physics, because the study of heat and the gaseous state were part of chemistry. Our modern sciences of zoology, botany, geology, and meteorology were all subsumed (at least in part) under natural history. The names zoology, botany, geology, and meteorology, which had been used earlier with slightly different meanings, were familiar, but both biology and sociology were names and fields that were created in the nineteenth century. During the eighteenth century all of these categories began to shift into the arrangements that are familiar to us today, but it was a gradual process. The creation of the new scientific disciplines was probably the most important contribution of the Enlightenment to the modernization of science, and one that we might easily overlook.” Thomas L. Hankins, *Science and the Enlightenment*, Cambridge History of Science Series (Cambridge: Cambridge University Press, 1985), 11.

tion of disciplines. The entire argument so far for the transformative character of textual traditions is summarized in Table 8.

In conclusion, Theories of the Earth were a contested textual tradition marked in part by the appropriation of hexameral idiom and the prominent deployment of global sections and views. As a textual tradition they served as an arena for vigorous general debate in the public sphere concerning the relation between natural order and historical contingency in the constitution of the Earth. To a historical delineation of that tradition we now turn.

TABLE 8. Textual Traditions and the Transformation of Disciplines

<table>
<tr><th>Description</th><th>Illustration</th></tr>
<tr><td>Transmogrification refers to a transformative process where the outcome cannot be predicted from the initial conditions. Watterson popularized the word with several series of “Calvin and Hobbes” strips, as in these two frames from Bill Watterson, The Calvin and Hobbes Tenth Anniversary Book (New York: Scholastic, Inc., 1995), 55.</td><td>
</td></tr>
<tr><td>As reflected in the title of Part I, Theories of the Earth may be broadly understood as a textual tradition bridging the cosmological changes of the seventeenth century with the emergence of geology and other historical sciences in the nineteenth century.</td><td>
</td></tr>
<tr><td>“From Cosmology to Geology” is too simplistic a characterization of the reconfiguration of disciplines before, during and after Theories of the Earth. Multiple disciplines were involved, including the ones listed on each side in this diagram (or mentioned in earlier sections of this chapter).</td><td>
</td></tr>
<tr><td colspan="2">(Some disciplines maintained an autonomous continuity throughout this time period despite their participation in Theories of the Earth, others were created or became obsolete for a variety of reasons, but all of them were involved to some degree in the multi-disciplinary discourse of Theories of the Earth.)</td></tr>
<tr><td>Given the character of Theories of the Earth as a textual tradition, it becomes interesting to ask to what extent the new configuration of disciplines reflects an historical sensibility toward nature as a result of participation in Theories of the Earth.</td><td>
</td></tr>
</table>

§ 4. Textual Criterion 1: Internal Attribution

§ 4-i. Titles

Numerous works entitled Theory of the Earth were published during the seventeenth and eighteenth centuries and after (Table 9). Inspection of the titles for works listed in Table 9 and published before the end of the seventeenth century shows that the phrase came into prominent circulation with Thomas Burnet's *Theory of the Earth* (1684; the first English edition of *Telluris Theoria Sacra*, 1681). Defenders and critics alike in the ensuing controversy referred to *The Theory of the Earth* simply as "the Theory." The author himself did not need to be mentioned by name; like medieval references to Aristotle as "the Philosopher" or Averröes as "the Commentator," unspecified allusions to "the Theorist" were universally understood.[186] This manner of speaking continued in English writings up through John Keill's 1698 attack on Burnet more than a dozen years after the first publication of *The Theory of the Earth*.[187] One defender against Keill's critique was Thomas Beverley, whose citation of Keill provides a clear example of such usage:

> But let us set down his [Keill's] words, that there may be no mistake or misrepresentation. "Another argument which may be brought to convince <u>the Theorist</u> that the Axis of the Earth was at first inclined to the Plane of the Ecliptick, is, that it is certain by observation, that Saturn and Jupiter (whom <u>the Theorist</u> will allow to have suffered no Deluge as yet) have their Axes not perpendicular but inclin'd to the Planes of their Orbits, and the position is true of all the other Planets, as far

[186] An early critique by Herbert Croft, Bishop of Hereford provides a hostile example: "we do not make God do any thing: but onely shew unto <u>this Theorist</u> (who will not allow God either to Create, or Multiply the Waters that were created, upon so great an occasion, as this Deluge) how God might do it without either Multiplying or Creating anew. I do it then to satisfie his curiosity rather than our own: for we rest satisfied with God's affirming that there was such a Deluge, and that it was caused by the breaking open of the Fountains, and opening the Windows of Heaven; whether partly or wholly by those means which Moses sets down, we do not positively affirm." Herbert Croft, Bishop of Hereford, *Some Animadversions Upon a Book Intituled the Theory of the Earth* (London: Printed for Charles Harper, 1685), 97.

[187] For example, Keill wrote: "I cannot but think it a strange and presuming boldness in <u>the Theorist</u> to assert, that Mountains are plac'd in no order one with another... and that if they are singly consider'd, they do not consist of any proportion of parts, that is referable to any design...." John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698), 54.

> as they can be observ'd. And therefore, &c." First, as to Saturn, I'm sure the Theorist never thought that Planet to be now in its original form, but to be broken, and to have already suffer'd a dissolution: as you may see in both Theories, English and Latin. Then as to the position of Jupiter, I know not whence he has this certain observation, that its Axis is oblique to the Plane of its Orbit. For Hugenius tells us just the contrary, and that it hath a perpetual Equinox. Let these things be examin'd, and hereafter let us be cautious how we take things upon the Examiner's word, if he be found to have committed two faults in one Objection.[188]

Thus Burnet's Theories were referred to as *texts* in both Latin and English. After the phrase entered common parlance, "Theory of the Earth" was applied by later writers to competing views such as William Whiston's *New Theory of the Earth* (1696).[189] And it was retrospectively attributed to earlier works before Burnet, such as Descartes' *Principia philosophiae* (1644). Indeed, Burnet derived the phrase "Theory of the Earth" from the title of Part IV of Descartes's *Principia*, although Descartes himself did not use it.[190]

TABLE 9. Works with titles containing the phrase Theory of the Earth

#	Date	Writer	Title
1.	**1644**	René Descartes	"Of the Earth," Part IV of Principia philosophiae
2.	**1681**	Thomas Burnet	Telluris Theoria Sacra
3.	**1684**	Thomas Burnet	Theory of the Earth

[188]Thomas Beverley, *Reflections upon the Theory of the Earth, Occasion'd by a Late Examination of It. In a Letter to a Friend* (London: W. Kettilby, 1699), 29–30; and Keill, *Examination*, 76. Cartesian (and Burnetian) interpretations of Saturn and other planets are discussed in Chapter 5. Huygens' argued for a perpetual equinox on Jupiter in Christian Huygens, *Kosmotheoros, sive De Terris Coelestibus, earumque ornatu, Conjecturae. Ad Constantinum Hugenium, Fratrem: Gulielmo III. Magnae Britanniae Regi, A Secretis* (Hagae-Comitum: Apud Adrianum Moetjens, Bibliopolam, 1698), 105.

[189]Keill again provides a convenient example, as when he implied that Whiston had fused Newtonian physics with the tradition of natural inquiry instanced, but not exhausted, by Burnet: "Tho' I think it impossible to give a True and Mechanical account, of that great Deluge of waters which once overflowed the Face of the whole Earth, it being a work not to be performed without the extraordinary contrivance of the Divine power; yet I cannot but acknowledge that Mr. Whiston the Ingenious Author of this new *Theory of the Earth,* has made greater discoveries, and proceeded on more Philosophical Principles than all the Theorists before him have done." Keill, *Examination,* p. 177.

[190]In the *Prinipia philosophiae* Descartes did not use the exact phrase "Theory of the Earth," but instead spoke of his "hypothesis" or "supposition" of the formation of the Earth. These terms had long been used to describe the starting premises or warranted foundations of reasoning in an astronomical system (cf. Descartes, Book III, chapter 15). The meaning of Descartes' terms and how Burnet appropriated Descartes' ideas as a "Theory" of the Earth are analyzed in "Baptizing Descartes," beginning on page 602.

TABLE 9. **Works with titles containing the phrase Theory of the Earth**

#	Date	Writer	Title
4.	**1685**	Herbert Croft	Some Animadversions Upon a Book Intituled the Theory of the Earth
5.	**1690**	Erasmus Warren	Geologia: or, a Discourse Concerning the Earth before the Deluge. Wherein the Form and Properties ascribed to it, in a Book intituled The Theory of the Earth, Are Excepted Against
6.	**1691**	Matthew Mackaile	Terrae Prodromus Theoricus
7.	**1693**	John Beaumont	Considerations on a Book, Entituled The Theory of the Earth, Publisht Some Years since by the Learned Dr. Burnet
8.	**1696**	Archibald Lovell	Summary of Material Heads Which may be Enlarged and Improved into a Compleat Answer to Dr. Burnet's Theory of the Earth
9.	**1696**	William Whiston	New Theory of the Earth
10.	**1697**	Robert St. Clair	Abyssinian Philosophy Confuted: or, Telluris Theoria neither Sacred, nor agreeable to Reason
11.	**1698**	John Keill	Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth
12.	**1699**	Thomas Beverley	Reflections upon the Theory of the Earth, Occasion'd by a late Examination of It
13.	**1705**	Georg Ernst Stahl, et al.	Pyrotechnical discourses, being I. An experimental confirmation of chymical philosophy, treating of the several principles in the animal, vegetable kingdoms; with a perspective against chymical nonentities, written by John Kunkel; II. A Short Discourse on the original of metallick veins, by George Ernest Stahl; which may serve as an answer to Dr. Woodward's Theory of the Earth, and was a forerunner to III. The Grounds of Pyrotechnical Metallurgy and Metallick Essaying by John Christian Fritschius ... all faithfully translated from the Latin
14.	**1729**	Louis Bourguet	Mémoire sur la théorie de la terre
15.	**1749**	Buffon	Histoire & Théorie de la Terre, Preuves de la Théorie de la Terre, in Histoire naturelle
16.	**1751**	Pierre-Augustin Boissier de Sauvages de la Croix	"Mémoire contenant des observations de lithologie, pour servir à l'histoire naturelle du Languedoc, & à la théorie de la Terre"
17.	**1764**	Georg Christoph Silberschlag	Neue Theorie der Erde
18.	**1769**	Joseph Needham	Une nouvelle Théorie de la Terre
19.	**1773**	William Worthington	Scripture Theory of the Earth throughout all its Revolutions
20.	**1780**	Philippe M. Bertrand	Lettre à M. le comte de Buffon; ou, Critique et Nouvel Essai sur la Théorie Générale de la terre

TABLE 9. **Works with titles containing the phrase Theory of the Earth**

#	Date	Writer	Title
21.	**1782**	Filippo Angelico Becchetti	Teoria generale della Terra
22.	**1782**	François Para du Phanjas	Theoria telluris, aquae, et aeris, vol. 2 of Theoria Entium Sensibilium
23.	**1783**	D. G. M.	Lettera di D. G. M. a sua Eccellenza Francesco Marindona in difesa di alcuni punti della Teoria della Terra
24.	**1784**	Horace-Bénedict de Saussure	"Agenda, Ou Tableau général des Observations et des Recherches dont les résultats doivent servir de base à la Théorie de la Terre"
25.	**1791**	Ermenegildo Pini	Saggio de una nuova Teoria della Terra
26.	**1788**	James Hutton	"Theory of the Earth," in Transactions of the Royal Society of Edinburgh
27.	**1795**	James Hutton	Theory of the Earth, with Proofs and Illustrations
28.	**1795**	Jean Claude Delamétherie	Théorie de la Terre
29.	**1797**	Philippe M. Bertrand	Nouveaux principes de géologie, comparés et opposés à ceux des philosophes anciens et moderns, notamment de J. C. Lamétherie, qui les a tous analysés dans sa Théorie de la terre
30.	**1799**	Philippe M. Bertrand	"Mémoire sur les questions élémentaires ou fondamentales d'une Théorie de la Terre." Journal de Physique
31.	**1799**	Charles Wilson Peale	Theory of the Earth
32.	**1802**	John Playfair	Illustrations of the Huttonian Theory of the Earth
33.	**1802**	John C. Murray	A Comparative View of the Huttonian and Neptunian Systems of Geology, in answer to the Illustrations of the Huttonian Theory of the Earth, by Professor Playfair
34.	**1803**	William Richardson	"Inquiry into the Consistency of Dr. Hutton's Theory of the Earth, with the Arrangement of the Strata and other Phenomenon on the Basaltic Coast of Antrim," Transactions of the Royal Irish Academy
35.	**1806**	Noel André	Théorie de la Surface Actuelle de la Terre, Ou plutôt Recherches impartiales sur le temps et l'agent de l'arrangement actuel de la surface de la terre, fondées, uniquement, sur les faits, san systême et sans hypothèse
36.	**1809**	Jean André Deluc	Examination of some Modern Geological Systems, and particularly of the Huttonian Theory of the Earth
37.	**1813**	Georges Cuvier	Essay on the Theory of the Earth (title of translation by Robert Kerr of Cuvier's Discours préliminaire)
38.	**1815**	John Kidd	Geological Essay on the Imperfect Evidence in Support of a Theory of the Earth

TABLE 9. Works with titles containing the phrase Theory of the Earth

#	Date	Writer	Title
39.	1816	Flamichon	Théorie de la Terre, Déduite de l'Organisation des Pyrénées et Pays Adjacens
40.	1817	Eugène Melchior Louis Patrin	"Esquisse d'une théorie de la Terre," in Nouveau Dictionnaire d'Histoire Naturelle, tome XIII
41.	1818	William Knight	Facts and Observations Towards Forming a New Theory of the Earth
42.	1823	Ira Hill	An Abstract of a New Theory of the Formation of the Earth
43.	1824	John Hay	Calculations Introductory to a New Theory of the Earth
44.	1825	George Poulett Scrope	Considerations on Volcanos…; Leading to the Establishment of a New Theory of the Earth
45.	1829	William Maclure	"Remarks on the Igneous Theory of the Earth," American Journal of Science
46.	1831	John Macculloch	System of Geology, with a Theory of the Earth and an Explanation of Its Connexion with the Sacred Records
47.	1838	Johann Nepomuk von Fuchs	Über die Theorien der Erde
48.	1839	William H. Fitton	"Huttonian Theory of the Earth," review of Lyell's Principles of Geology in the Edinburgh Review
49.	1850	Archibald Tucker Ritchie	The Dynamical Theory of the Formation of the Earth
50.	1875	James Bradford Babbitt	Theory of the Earth; or, The Periodically Recurring Superficial Changes, or Geological Revolutions, in the Earth's Crust; also, The Changes in the Organic World, Indicated in the Geological Record; together with the proximate cause of the same, viz: the Climatal Vicissitudes of Former Times, Considered with Reference to the Proper Motion of the Earth, Involved in the Astronomical Appearance known as the 'Diminution of the Obliquity of the Ecliptic to the Equator'
51.	1908	Edgar Theodore Wherry	A New Theory of the Earth
52.	1988	Warren S. Carey	Theories of the Earth and Universe
53.	1989	Don L. Anderson	Theory of the Earth
54.	1994	Herbert R. Shaw	Craters, Cosmos, and Chronicles: A New Theory of the Earth

In addition to the prominence of Burnet's *Theory of the Earth* for establishing the discourse, Table 9 immediately suggests three further points:

- A similar clustering in the use of the phrase in book titles followed the publication of works by two additional writers: Georges Louis Leclerc, Comte de Buffon (1707–1788; *Histoire Naturelle* in 1749), and James Hutton (1726–1797; "Theory of the Earth" in 1788).[191]
- Although the works of Burnet, Buffon, and Hutton were paradigmatic for the tradition at various times, yet it is clear that the term "Theory of the Earth" was by no means confined to works written by, or engaging solely with, these three major figures.
- Finally, although there was no sudden, abrupt cessation of the tradition, during the generations of Cuvier and Lyell use of the phrase gradually subsided as the tradition differentiated into technical disciplines or was displaced by other discourses.

These points provide a first rough delineation of the Theories of the Earth tradition.

[191]For a consideration of Buffon's Theory see "Ornamental Global Views in Buffon's Histoire naturelle," beginning on page 379; for Hutton see "Hutton and the Whig Interpretation of Geology," beginning on page 269.

§ 4-ii. Catchwords and Synonyms

By itself Table 9 is misleading as a guide to the contours of the Theory of the Earth tradition, because "Theory of the Earth" was not the only phrase used for titles of texts which:

(1) *identified themselves as "Theories of the Earth,"* or

(2) *engaged other Theories in extensive debate,* or

(3) *were in turn widely regarded as "Theories of the Earth" by later writers.*

Not even the first of these textual criteria, summarized in Table 10, is exhausted by the works listed in Table 9. Certain phrases other than "Theory of the Earth" became common catchwords marking the tradition as well.

TABLE 10. Textual criteria for participation in Theories of the Earth[a]

Textual Criterion	Description	Examples
1. Internal attribution	"identified themselves as 'Theories of the Earth'"	Titles (Table 9) Catchwords and Synonyms
2. Participation	"engaged other Theories in extensive debate"	Reviews and refutations of Theories of the Earth
3. External attribution	"were in turn widely regarded as 'Theories of the Earth' by later writers"	Descartes, Werner, Cuvier

a. To specify these textual criteria does not disregard criteria of relevance considering the local roles of serious readers or critical sources in shaping the tradition. However, to include such criteria here would inflate the delineation of the tradition beyond meaningful bounds. I argue below that to delineate Theories of the Earth as a textual tradition in actuality facilitates consideration of relevant local and non-textual contexts which are overlooked by those who narrowly define Theories of the Earth as a conceptual mentality or genre of thought; see " Keill and the Local Intersection of Contested Textual Traditions," beginning on page 143.

§ 4-ii-a. System of the Earth

"System of the Earth" provides a clear example of an equivalent phrase. The use of "System" as a synonym for "Theory" is evident from the works listed in Table 9 by John Murray (1802), Jean André Deluc (1809), and John Macculloch (1831). James Hutton's Theory of the Earth was published in three versions, including a brief "System of the Earth" abstract

(1785) as well as the two later versions entitled "Theory of the Earth" (1788 and 1795).[192] An earlier example is Claude Gadroys' *Système du monde* (1675), which includes a Theory of the Earth that closely followed Descartes.[193] The use of "system" to refer to organized knowledge had been conventional since, for example, the construction of astronomical "Theories" of the motions of planets according to the Ptolemaic cosmological "system."[194]

However, just as with "Theory," the meaning of the term was attended with debate. Throughout the seventeenth and eighteenth centuries, various efforts were made to articulate and defend criteria for productive and legitimate systematizing. However, such criteria were more easily stated than applied. As late as the turn of the nineteenth century writers self-consciously exemplifying the "spirit of system," such as Hutton and Lamarck, were still defending the legitimacy of their ideal in terms of constructing a "System of the Earth." On the other hand, "systems" of the Earth were more likely to heed the methodological warnings and rhetorical conventions established by the *Discours préliminaire* to the first volume of the *Encyclopédie* (1751), an Enlightenment manifesto distilling the attitudes of the *philosophes.* In this masterful essay on the progress of knowledge, D'Alembert's *Discours préliminaire* drove home

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[192]James Hutton, "Abstract of a Dissertation read in the Royal Society of Edinburgh, upon the Seventh of March, and Fourth of April, M,DCC,LXXXV, concerning the System of the Earth, its Duration, and Stability"; "Theory of the Earth; or an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe," *Transactions of the Royal Society of Edinburgh* 1 (1788): 209–304; facsimiles of the original editions with an introduction by Victor A. Eyles are available as *James Hutton's System of the Earth, 1785; Theory of the Earth, 1788; Observations on Granite, 1794; together with Playfair's Biography of Hutton,* ed. George W. White, Contributions to the History of Geology, vol. 5 (New York: Hafner Press, 1973). Subsequently Hutton published an extended version as *Theory of the Earth, with Proofs and Illustrations,* 2 vols. (Edinburgh: for Cadell and Davies, London, 1795); facsimile reprint James Hutton, *Theory of the Earth, with Proofs and Illustrations,* 2 vols., Historiae Naturalis Classica series (Codicote, Herts.: Verlag von J. Cramer, 1972). A manuscript for an unprinted third volume was published a century later: James Hutton, *Theory of the Earth, with Proofs and Illustrations,* ed. Archibald Geikie, vol. 3 (London: Geological Society, 1899); reprinted Dennis R. Dean, ed., *James Hutton in the field and in the study, an augmented reprinting of vol. III of Hutton's "Theory of the earth" (I, II, 1795), as first published by Sir Archibald Geikie (1899)* (Delmar, N.Y.: Scholars' Facsimiles & Reprints, 1997). See Victor Ambrose Eyles, "Note on the Original Publication of Hutton's *Theory of the Earth,* and on the Subsequent Forms in which it was Issued," *Proceedings of the Royal Society of Edinburgh,* Section B, 63 (1948–1949): 377–386. Hutton is discussed below; see "Hutton and the Whig Interpretation of Geology," beginning on page 269.

[193]Claude Gadroys, *Le Système du Monde, Selon les Trois Hypothèses* (Paris: Chez Guillaume Desprez, 1675). Gadroys is discussed in "Cartesian Cosmogonies," beginning on page 557.

[194]Olaf Pederson, "The Theorica-planetarum Literature of the Middle Ages," *Actes du Dixième Congrès International d'Histoire des Sciences* (1962): 615–618, and Olaf Pederson, *Early Physics and Astronomy: A Historical Introduction* (1993; revised edition Cambridge: Cambridge University Press, 1993).

the idea that progress in knowledge requires reasoning from phenomena rather than uncritical acceptance of the authority of established religious and political traditions. D'Alembert attempted to distinguish between a "systematic spirit" (*esprit systématique*) properly grounded in observations and quantitative arguments, explaining facts by means of other facts in the manner of Newtonian analysis and synthesis (an approach which D'Alembert practiced in his mathematical works), and an outmoded "spirit of system" (*l'esprit de systême*) rooted in physical conjectures and deductions from metaphysical principles.[195] D'Alembert argued that the obsolescence of *l'esprit des systèmes* was manifest in the metaphysics of Leibniz and the natural history of Buffon, despite conceding its utility during immature stages of inquiry as in the case of Descartes. It was not a coincidence that D'Alembert offered his clearest statement immediately after complimenting Buffon's *Histoire naturelle* only for its style.[196]

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[195]Cf. the contrast between demonstration *propter quid* and the demonstrative regress on page 32ff.

[196]Jean Le Rond D'Alembert, "Discours préliminaire des editeurs," in *Encyclopédie,* vol. 1, 17 vols. (Paris: Briasson, 1751), page numbers in Roman numerals from the first volume; page numbers given in brackets are from D'Alembert, *Preliminary Discourse to the Encyclopedia of Diderot,* trans. Richard N. Schwab (Chicago: University of Chicago Press, 1995); hereafter D'Alembert, "Discours préliminaire." The clear statement of the distinction following a paragraph on Buffon is on page xxxi [94–96]: "But while intending to please, philosophy seems not to have forgotten that it is designed principally to instruct. For that reason the taste for systems—more suited to flatter the imagination than to enlighten reason—is today almost entirely banished from works of merit.... The spirit of hypothesis and conjecture [*l'esprit d'hypothèses & de conjecture*] formerly was perhaps quite useful and even necessary for the renaissance of philosophy, because at that time judiciousness was less important than acquiring independence of thought. But times have changed, and a writer among us who praised systems would have come too late.... The spirit of systems [*L'esprit des systèmes*] is in physics what metaphysics is in geometry. If it may sometimes be required to start us on the way, it is almost never capable by itself of leading us to truth. It can glimpse the causes of phenomena when enlightened by the observation of Nature; but it is for calculations to assure, so to speak, the existence of these causes by determining exactly what effects they can produce and by comparing these effects with those revealed to us by experience. Any hypothesis without such a support rarely acquires that degree of certitude which ought always to be sought in the natural sciences, and which is so seldom found in those frivolous conjectures honored by the name of 'systems.'..." D'Alembert's remarks on systems are consistent with the extensive argument made by his friend, the abbé Condillac, in *Traité des systèmes* (1749), which D'Alembert cited in a footnote to this paragraph. On D'Alembert's conception that reasoning from phenomena rather than arbitrary hypotheses constitutes the true systematic spirit see page vi [22], and the comment of Schwab [22, note]; page vi introduces the distinction later elaborated: "Cette réduction, qui les rend d'ailleurs plus faciles à faisir, constitue le véritable esprit systématique, qu'il faut bien se garder de prendre pour l'esprit de systême avec lequel il ne se rencontre pas toûjours." On the respect due Descartes despite his *esprit de systéme*, see 1: xxvi [78–79]; on the metaphysical transgressions of Leibniz, 1: xxviii [86–87]. Although the metaphysical system of Leibniz might be dangerous, D'Alembert conceded that in the generation of Descartes "physicists had to be carried forward almost in spite of themselves," 1: xxvi [79].

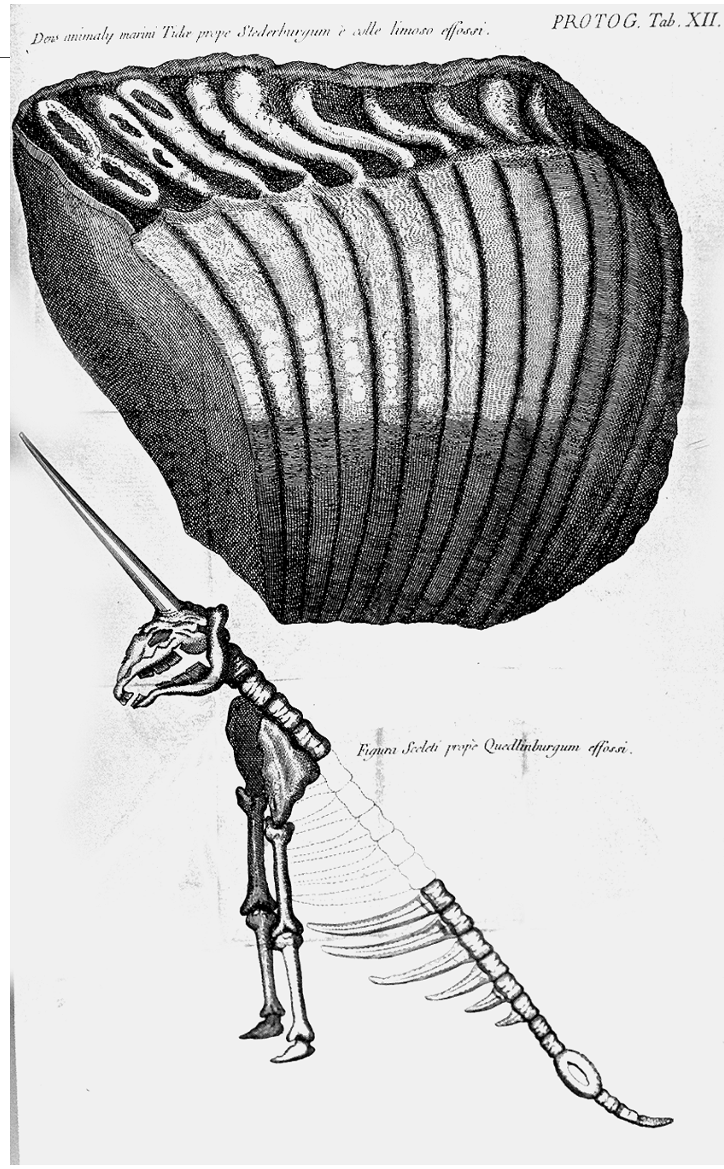

FIGURE 7. Leibniz, *Protogaea* (1749), *Tab XII*. HSCI.

Explanation. Above: fossil tooth found near Stederberg, "Dens animaly marini Tidae prope Stederburgum è colle limoso effossi" (later shown to be from a mammoth). Below: reconstruction of the skeleton of a unicorn found near Quedlinbourg, "Figura Sceleti propè Quedlinburgian effossi" (shown by Cuvier to be a rhinoceros).

Buffon has already been quoted on this matter,[197] but the example of D'Alembert's treatment of Leibniz is instructive. D'Alembert criticized only Leibniz's metaphysics in the *Discours préliminaire*, not his Theory of the Earth. Although ideas from the latter are occasionally embedded in metaphysical works such as his *Theodicy*,[198] his Theory was written as the prologue to an historical narrative of the House of Brunswick, and relied heavily upon empirical evidence gathered both from his experience in administrating mines and from his attempts to reconstruct fossil animal bones. Of the twelve

[197] See quote on page 53.

[198] For example, section 6 of Leibniz's *Protogaea* is summarized in Part III, paragraphs 244–245 of the *Theodicy*; Gottfried Wilhelm Leibniz, *Theodicy: Essays on the Goodness of God, the Freedom of Man and the Origin of Evil*, trans. E. M. Huggard, ed. Austin Farrer (Chicago: Open Court, 1985), 278. For the role of pre-ordained harmony in Leibniz's Theory of the Earth see footnote 259 on page 556.

plates accompanying the *Protogaea*, one shows a section of Baumann's cavern and the other eleven depict fossil remains (Figure 7).[199] Leibniz did not title his Theory a "system of the Earth," but even though it was outdated by the mid-eighteenth century (having been selectively and fruitfully appropriated by Bourguet, Buffon and others) it was not easily subject to the kinds of criticisms D'Alembert levelled at his metaphysical system.[200]

Burkhardt identifies an underlying problem regarding "the spirit of system" which made it difficult in general for D'Alembert and others consistently to reconcile practice with rhetoric:

> By the 1790s, there was already a long history of polemics regarding the proper role of facts and hypotheses in science. 'System-building' had been identified early in the century as one of the greatest obstacles to scientific progress, and from Fontenelle to Condillac the 'esprit de système' had been castigated. Separating fact from theory was not considered difficult, at least not in principle. But counseling a greater attention to facts only sidestepped the major issue: how was one to know when enough observations had been made so that generalizations connecting diverse phenomena could be attempted successfully? Happy would be the man, Condillac suggested, who lived in a time that furnished him with enough

[199]In addition to the paragraphs in the *Theodicy*, Leibniz's Theory of the Earth was published in his lifetime primarily in the form of a brief summary; Gottfried Wilhelm Leibniz, "Protogaea," *Acta eruditorum* (1693): 40–42; reprinted with notes in David R. Oldroyd and J. B. Howes, "The First Published Version of Leibniz's *Protogaea*," *Journal of the Society for the Bibliography of Natural History* 9 (1978): 56–60. Rappaport has discovered a transcript of 1706 paper read to the Paris Academy of Sciences; Rhoda Rappaport, "Leibniz on Geology: A Newly Discovered Text," *Studia Leibnitiana* 29 (1997): 6–11. The full text of the *Protogaea* appeared only in 1749; Gottfried Wilhelm Leibniz, *Protogaea sive de prima facie telluris et antiquissimae historiae vestigiis in ipsis naturae monumentis dissertatio ex schedis manuscriptis Viri Illustris in lucem edita a Christiano Ludovico Scheidio* (Göttingen: Sumptibus Ioh. Guil. Schmidii, 1749), which was translated into German as Gottfried Wilhelm Leibniz, *Protogaea, oder Abhandlung von der ersten Gestalt der Erde und den Spuren der Historie in den Denkmaalen der Natur, trans. Christian Ludwig Scheid* (Leipzig und Hof: bey Johann Gottlieb Vierling, 1749). A convenient modern edition of the Latin text with a French translation is Gottfried Wilhelm Leibniz, *Protogaea: De l'aspect primitif de la terre et des traces d'une histoire très ancienne que renferment les monuments memes de la nature*, trans. Bertrand de Saint-Germain, ed. Jean-Marie Barrande (Toulouse: Presses Universitaires de Mirail, 1993). For a summary of the publishing history of Leibniz' Theory see Rhoda Rappaport, "Leibniz on Geology: A Newly Discovered Text," *Studia Leibnitiana* 29 (1997): 6–11. An excellent guide to the many aspects of Leibniz' life and thought is Nicholas Jolley, ed., *The Cambridge Companion to Leibniz* (Cambridge: Cambridge University Press, 1995), particularly the chapter by Roger Ariew, "G. W. Leibniz, Life and Works," pp. 18–42. On the use of "monuments" in the contexts of natural history and antiquarianism, see Rhoda Rappaport, "Borrowed Words: Problems of Vocabulary in Eighteenth-Century Geology," *British Journal for the History of Science* 15 (1982): 27–44. On Leibniz's mining experience see Ernst P. Hamm, "Knowledge from Underground: Leibniz Mines the Enlightenment," *Earth Sciences History* 16 (1997): 77–99. Roger Ariew explores Leibniz' natural history collecting in "Leibniz on the Unicorn and Various Other Curiosities," *Early Science and Medicine* 3 (1998): 267–288.

[200]In contrast to the *Protogaea*, Leibniz did describe his metaphysics as a system in one of its earliest expositions, the "Systême nouveau de la nature et de la communication des substances, aussi bien que de l'union qu'il y a entre l'âme et le corps," *Journal des Savants* (1695).

> facts so that he did not have to use his imagination. But how was one to realize when that time had arrived?[201]

It is no wonder that D'Alembert himself was not able consistently to uphold his distinction between a systematic spirit and the spirit of system.[202] One does not reject the ideal of a unified system of knowledge (e.g., "the Theory of the Earth") simply by wishing to substitute for a system based on conjectures a more reliable systematic approach based on facts. Yet when known facts change then what had seemed like a systematic approach in one time and place may be regarded shortly thereafter as the spirit of system.[203]

Controversy over the characteristics of appropriate theorizing was ongoing and is considered further in Chapter 3, but this preliminary discussion of D'Alembert and Leibniz manifests four caveats:

- Some kind of distinction between a proper grounding in observational evidence and bold extensions of untested metaphysical conjectures was almost always hailed in principle (Descartes being the only major exception).
- In practice this distinction proved exceedingly contentious to apply, particularly when there was little consensus regarding which *kinds* of evidence were most relevant and reliable. The privileging of particular kinds of evidence by one writer could be dismissed by another as an error caused by metaphysical speculation.
- Theorists of the Earth span the continuum from cautious observers with a systematic bent, who claim to organize factual knowledge without indulging in unwarranted hypotheses (such as Saussure, Deluc and Macculloch), to those who by their own account pursued a more daring spirit of system (such as Hutton and Lamarck).

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[201] Richard W. Burkhardt, Jr., *The Spirit of System: Lamarck and Evolutionary Biology* (Cambridge: Harvard University Press, 1977), 39. Burkhardt analyzes Lamarck's Theory of the Earth in chapter 4, 94–114.

[202] Despite D'Alembert's attack on metaphysical systems, his own theory of the unity of knowledge as a great chain of connected geometrical truths seems equally rationalistic and therefore subject to similar ambiguity. Consider Burkhardt's question with respect to D'Alembert: "how was one to know when enough observations had been made so that generalizations connecting diverse phenomena could be attempted successfully?" One wonders whether D'Alembert's following statement is derived from observation in a systematic spirit, or whether in generalizing to the universe as a whole it partakes of the character of the spirit of system: "It is the same with the physical truths and with the properties of bodies whose connection we perceive. All of these properties gathered together offer us, properly speaking, only a simple and unique piece of knowledge.... That power of attracting small bodies which [electrical bodies] acquire when rubbed, and that of producing a violent commotion in animals, are two things for us. They would be a single one if we could reach the primary cause. The universe, if we may be permitted to say so, would only be one fact and one great truth for whoever knew how to embrace it from a single point of view." D'Alembert, "Discours préliminaire," ix [29].

[203] No clearer example of this non-permanency of facts can be found, perhaps, than in the rhetoric of Cuvier. See "Controversy and the Rhetoric of Demarcation," beginning on page 307.

- Remarkably often a Theorist appears in double-vision, at both poles of the continuum between D'Alembert's systematic spirit and the spirit of system, depending on which page is turned, which contemporary is asked, or which kind of evidence is privileged.

The last caveat, and the consequent blurring of the distinction, suggests that it would be difficult to exclude any contemporary work centrally invoking a phrase such as "system of the Earth" from the Theory of the Earth tradition.

§ 4-ii-b. Natural History of the Earth

Inquiry in seventeenth-century "natural philosophy" sought to integrate causal or demonstrative natural knowledge in a comprehensive system manifesting the unity of truth.[204] While Theories of the Earth from Descartes to Whiston to Hutton could be expressed in terms of the aims of natural philosophy, not all Theories of the Earth were presented as theoretical exercises in natural philosophy. Natural history could be equally comprehensive and systematic. The boundaries between natural philosophy and natural history were not clear-cut, but soft and semi-permeable. Thomas Robinson's *New Observations on the* *<u>Natural History</u> of this World of Matter, and this World of Life,* published in 1696, included an explanatory subtitle:

> Being a <u>Philosophical</u> Discourse, grounded upon the Mosaic <u>System</u> of the Creation, and the Flood. To which are added Some Thoughts concerning Paradise, the Conflagration of the World, and a Treatise of Meteorology: With occasional Remarks upon some late Theories, Conferences, and Essays.[205]

The use of "Natural History" in Robinson's title emphasized its purportedly factual basis in "New Observations," a synthesis of natural philosophy and natural history. This usage fol-

[204] The comprehensiveness of seventeenth-century natural philosophy is emphasized by Andrew Cunningham, "How the *Principia* got Its Name; Or, Taking Natural Philosophy Seriously," *History of Science* 29 (1991): 377–392. Compare the discussion of the epistemic aims of causal reasoning, phenomenalism and natural history above, page 30ff.

[205] Thomas Robinson, *New Observations on the Natural History of this World of Matter, and this World of Life: In Two Parts. Being a Philosophical Discourse, grounded upon the Mosaic System of the Creation, and the Flood. To which are added Some Thoughts concerning Paradise, the Conflagration of the World, and a Treatise of Meteorology: With occasional Remarks upon some late Theories, Conferences, and Essays* (London: Printed for John Newton at the Three-Pigeons, 1696).

lowed the example of John Woodward's well-known Theory, published the previous year.[206] Woodward began with a section entitled "An Account of the Observations Upon which this Discourse is Founded," in which he emphasized the critical role of evidence obtained through his study of extraneous fossils.[207] By entitling his work as a *Natural History of the Earth* Woodward emphasized its factual and descriptive foundations as an enterprise of natural history. This convention was adopted by a host of other writers concerned, like Woodward, with extraneous fossils (in cabinet collections, museums, or in the field) and mineralogy (widely regarded as one of the three branches of natural history). A famous passage from a writer regarded today as a diligent observer and descriptive fact-gatherer in contrast to Theorists of the Earth confirms the impression that Theories of the Earth were widely regarded as entirely pertinent to the endeavors of natural history:

> I do not wonder that so little progress has been made in the improvement of Natural History, and particularly in that branch of it which regards the Theory of the Earth. ….Those who have made this subject their study, have without scruple, undertaken at once, to write the Natural History of a whole province, or of an entire continent; not reflecting, that the longest life of man scarcely affords him time to give a perfect one of the smallest insect.[208]

[206]John Woodward, *An Essay toward a Natural History of the Earth: and Terrestrial Bodies, Especially Minerals: As also of the Sea, Rivers, and Springs. With an Account of the Universal Deluge: And of the Effects that it had upon the Earth* (London: Printed for Ric. Wilkin, 1695; available as a facsimile reprint in the History of Geology Series, Ayer Publishing [no date]).

[207]"From a long train of Experience, the World is at length convinc'd, that Observations are the only sure Grounds whereon to build a lasting and substantial philosophy.... For which reason, I shall in the Work before me, give my self up to be guided wholly by Matter of Fact;... and not to offer any thing but what hath due warrant from Observations; and those both carefully made, and faithfully recorded." John Woodward, *An Essay toward a Natural History of the Earth: and Terrestrial Bodies, Especially Minerals: As also of the Sea, Rivers, and Springs. With an Account of the Universal Deluge: And of the Effects that it had upon the Earth* (London: Printed for Ric. Wilkin, 1695), 1–2.

[208]William Hamilton, *Observations on Mount Vesuvius, Mount Etna, and Other Volcanos: In a Series of Letters, Addressed to the Royal Society… To which are added, Explanatory Notes by the Author, hitherto unpublished*. A New Edition (London: Printed for T. Cadell, in the Strand, 1774), 92–93. John Thackray's excellent study of Hamilton's observations of Vesuvius is not undermined by his unfortunate, preliminary caricature of Theorists of the Earth as "not themselves observers," in contrast to Hamilton; John Thackray, "'The Modern Pliny': Hamilton and Vesuvius," in *Vases and Volcanoes: Sir William Hamilton and His Collection,* ed. Ian Jenkins and Kim Sloan, 65–74 (Published for the Trustees of the British Museum by British Museum Press, 1966), 65. Hamilton's relationship to the Theory of the Earth tradition is much more problematic than conventional caricatures of the latter allow, and is considered in "Hamilton and Literary Genres of Theories of the Earth," beginning on page 159; this quote is discussed on page 168.

Other examples are as varied as John Harris (1697), Louis Bourguet (1742), John Hutchinson (1748), Immanuel Kant (1755), Rudolf Raspe (1763), Jean André Deluc (1803), Robert Jameson (1818), or Robert Chambers (1844).[209] As noted in the previous section, the distinction between systematists and system builders is impossible consistently to apply, and there is no correlation between natural history and descriptive systematists, on the one hand, vs. natural philosophy and system builders on the other.

§ 4-ii-c. Revolutions of the Globe

Buffon and Cuvier published their Theories as preliminary treatises in multi-volume works of natural history.[210] Cuvier's "Discours préliminaire" (1812) was later published as a *Discours sur les révolutions de la surface du globe* (1825), and became known in Britain and

[209]Examples of the use of "natural history" and its cognates are easily multiplied: In addition to Robinson's work just cited above, see Thomas Robinson, *An Essay Towards a Natural History of Westmorland and Cumberland, Wherein an Account is given of their several Mineral and Surface Productions, with some Directions how to discover Minerals by the External and Adjacent Strata and Upper Covers, &c. To which is Annexed, A Vindication of the Philosophical and Theological Paraphrase of the Mosaick System of the Creation, &c* (London: Printed by J. L. for W. Freeman, at the Bible against the Middle-Temple-Gate in Fleetstreet, 1709). Woodward's Theory was largely endorsed in, for example, John Harris, *Remarks on some Late Papers, Relating to the Universal Deluge: And to the Natural History of the Earth* (London: Printed for R. Wilkin, 1697); and contested in, for example, John Hutchinson, *An Essay Toward a Natural History of the Bible, Especially Of some Parts which relate to the Occasion of revealing Moses's Principia,* 3d ed., vol. 1 of *Hutchinson's Works,* 12 vols., 1–272 (London: Printed for J. Hodges, at the Looking-Glass, over-against St. Magnus's Church, London-Bridge, 1748). Woodward was also followed by Louis Bourguet, *Mémoires pour servir a l'histoire naturelle des petrifactions dans les quatre parties du monde* (La Haye: J. Neaulme, 1742); Louis Bourguet, *Memoirs useful for the natural history of petrifactions in the four quarters of the world,* trans. Raymond L. Nace (Columbus, Ohio: Coral Press, 1981). Distant from Woodward's direct influence was Immanuel Kant, *Allgemeine Naturgeschichte und Theorie des Himmels oder Versuch von der Verfassung und dem mechanischen Ursprunge des ganzen Weltgebäudes nach Newtonischen Grundsätzen abgehandelt* [Universal Natural History and Theory of the Heavens, or an Essay on the Constitution and Mechanical Origin of the Whole Universe, treated according to Newtonian Principles] (Königsberg: J. F. Petersen, 1755). Later examples include numerous articles in the *Memoirs of the Wernerian Natural History Society,* such as Robert Jameson, "Mineralogical Observations and Speculations," 2 (1818): 221-231; Rudolf Erich Raspe, *Specimen Historiae Naturalis Globi Terracquei, praecipue De Novis e Mari Natis Insulis, Et ex his exactiùs descriptis & observatis, ulteriùs confirmandâ, Hookiana Telluris Hypothesi, De Origine Montium et Corporum Petrefactorum* (Amsterdam & Leipzig: Sumptibus J. Schreuder & P. Mortier, 1763); Jean André Deluc, *Annonce d'un ouvrage de Mr. J. A. Reimarus, Professor of Physics and Natural History at Hamburg, sur la formation du Globe* (Hannover, 1803); Robert Chambers, *Vestiges of the Natural History of Creation* (London: John Churchill, Princes Street, Soho, 1844), etc.

[210]Georges Louis Leclerc Comte de Buffon, "Histoire & Théorie de la Terre," and "Preuves de la Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi. Tome Premier* (Paris: De l'Imprimerie Royale, 1749), 65–124, 125–612. Georges Cuvier, "Discours préliminaire," in *Recherches sur les Ossemens Fossiles de quadrupedes*, 5 vols. (Paris: Chez Deterville, 1812), 1: 1–116; often reprinted, most recently as Georges Cuvier, *Discours sur les révolutions de la surface du globe et sur les changemens qu'elles ont produits dans le règne animal,* with a preface by Hubert Thomas and a postface by Goulven Laurent (Paris: Bourgois, 1985).

America through an often-reprinted translation entitled simply *Essay on the Theory of the Earth* (1813).[211] "Revolution" was another common indicator of a Theory of the Earth. As used in Cuvier's post-Revolutionary era title, "revolution" alluded to a catastrophic change in the state of the Earth (or a region of the Earth) wherein new flora and fauna displaced an older regime. This was the sense implied by Cuvier which came into vogue with Theorists after him.[212] However, "revolution" was used during the *ancien régime* a half-century before Cuvier and, because it originated as an astronomical metaphor referring to the regular order of the law-bound motions of the heavens, it did not necessarily carry catastrophic or violent connotations.[213] Yet even if an astronomical agent were invoked the results still could be catastrophic. Lawbound comets moving in closed orbits could produce rare, violent events. For example, Johann Gottlob Krüger's *Geschichte der Erde in den Allerältesten Zeiten* (1746) was shortly translated into French as *Histoire des Anciennes Revolutions du Globe Terrestre* (1752). Krüger (1715-1759), a professor of medicine at the University of Halle also known for works on physics and electricity, began with a critical history of theories of the origin and shape of the Earth in which he cautiously approved of William Whiston's Theory of cometary impacts.[214] Regardless of whether "revolutions" were envisioned as the consequences of regular operations

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[211] Georges Cuvier, "Discours préliminaire," in *Recherches sur les Ossemens Fossiles de Quadrupedes, ou l'on Rétablit les Caractères de Plusieurs Espèces D'Animaux que les Révolutions du Globe Paroissent avoir Détruites*, vol. 1, 4 vols. (Paris: Chez Deterville, 1812), 1–120; Georges Cuvier, *Discours sur Les Révolutions de la surface du globe, et sur les changemens qu'elles ont produits dans le règne animal*, 3d ed. (Paris, et à Amsterdam: chez G. Dufour et Ed. d'Ocagne, 1825); Georges Cuvier, *Essay on the Theory of the Earth. Translated from the French of M. Cuvier … by Robert Kerr. With Mineralogical Notes, and an Account of Cuvier's Geological Discoveries, by Professor Jameson* (Edinburgh: Printed for William Blackwood; and John Murray, and Robert Baldwin, 1813). Cuvier's work is discussed below; see "Controversy and the Rhetoric of Demarcation," beginning on page 307.

[212] Another example of revolutions in a catastrophic sense is Adhémar's Theory, considered in chapter 2; Joseph Alphonse Adhémar, *Révolutions, De la Mer* (Paris: Carilian-Goeury et V. Dalmont, 1842). However, the catastrophes envisioned by the revolutions of Buffon and Cuvier has sometimes been overemphasized; cf. the caveats in footnote 91 on page 312.

[213] In astrological writings "revolution" had long been used to refer to an annual prediction without carrying any necessarily catastrophic connotation. The usage and changing meanings of "revolution" are explored in I. Bernard Cohen, *Revolution in Science* (Cambridge: The Belknap Press of Harvard University Press, 1985); Rhoda Rappaport, "Borrowed Words: Problems of Vocabulary in Eighteenth-Century Geology," *British Journal for the History of Science* 15 (1982): 27–44; and François Ellenberger, "Étude du Terme *Révolution*," in *Documents Pour l'Histoire du Vocabulaire Scientifique*, vol. 9, Publications de l'Institut de la Langue Française (Besançon-Nancy: Institut de la Langue Française, 1980–1989), 69–90.

or rare events, phrases such as “the revolutions of the Earth” were associated with Theories of the Earth.

§ 4-ii-d. Geognosy and the Wernerian Adaptive Radiation

Other terms were coined in attempts to differentiate from the Theory of the Earth tradition as a whole some particular approach to a specific problem raised in the tradition. As a case in point, Abraham Gottlob Werner (1749–1817) referred to descriptive fieldwork establishing the succession and extent of rock formations as *geognosy*.[215] Geognosy represents one conformable contact between Theories of the Earth and geology insofar as the technical tradition of geognosy proved to be at least as successful as other technical traditions (e.g., mathematical cosmology or geodesy) in resolving problems featured in the textual tradition of Theories of the Earth. In his *Kurze Klassifikation* Werner standardized definitions and nomenclature by distinguishing over thirty distinct rock formations (*gebirgsarten*).[216] While the *Kurze Klassifikation* was not intended as a treatise on the history of the Earth, Werner assigned rock formations to four classes distinguished primarily by their epoch and mode of origin rather than their mineralogical character (Table 11):

[214] Johann Gottlob Krüger, *Geschichte der Erde in den Alleraltesten Zeiten* (Halle: in der Lüderwaldischen Buchhandlung, 1746); *Histoire des Anciennes Revolutions du Globe Terrestre* (Amsterdam and Paris: Damonneville, 1752). Cf. Johann Ludwig Christ, *Geschichte unseres Erdkörpers, von den ersten Zeiten der Schöpfung des Chaos an: und von den Revolutionen desselben durch Vulkane, Erdbeben und Überschwemmungen* (Frankfurt, Leipzig, 1785).

[215] Werner's Theory of the Earth was published as Abraham Gottlob Werner, “Kurze Klassifikation und Beschreibung der Verschiedenen Gebirgsarten,” *Abhandlungen der Böhmischen Gesellschaft der Wissenschaften* 2 (1786): 272–297; and is conveniently available as *Short Classification and Description of the Various Rocks,* trans. Alexander M. Ospovat with introduction, notes, and facsimile of the original text (New York: Hafner Press, 1971); hereafter, “Ospovat.” Werner coined the term *geognosy* to designate one of his five divisions of mineralogy (Ospovat, p. 101). The other divisions were *oryctognosy*, which involved the identification and nomenclature of minerals; *mineralogical chemistry*, which included assaying and chemical analysis; *mineralogical geography*, which attended to distribution; and *economic mineralogy*, which considered applications and utility. Werner began offering his course on geognosy in 1778 (Ospovat, p. 30). His *Kurze Klassifikation* was reprinted as a pamphlet at least twice shortly after its original publication. Ospovat's English composite translation is based on these three printed sources and two manuscripts in Werner's hand. On the basis of manuscript evidence, Ospovat showed that Werner wrote the *Kurze Klassifikation* between 1783 and 1785, probably as a synopsis or condensed abstract of the second part of his lectures on geognosy (Ospovat, pp. 6-17).

1) *Uranfanglichen gebirgsarten* or ***Primitive*** formations included those "of the oldest origin" which "show all the characteristics of aqueous formation."[217]

2) ***Flötzgebirgsarten*** or *horizontally-stratified* formations formed more recently than the primitive rocks, as a consequence of the mechanical destruction of primitive formations.

•Werner noted that "it is entirely possible that the (mode of) formation of the latter [*Primitive*] gradually changed into that of the former [*Flötz*]." Developing this conjecture not long after the publication of the *Kurze Klassifikation,* Werner established an intermediate class of ***Transition*** formations, which originated by a combination of chemical and mechanical processes.[218]

3) *Vulkanischen gebirgsarten* or ***Volcanic*** formations "owe either their entire existence to fire, or at least their alteration to it."[219]

4) ***Aufgeschwemmten*** *gebirgsarten* or ***Alluvial*** deposits were of most recent origin, though "the ages of formation of the last three main categories of rocks fall into almost the same period of time…"[220]

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[216]In his introduction to Werner's *Kurze Klassifikation*, Ospovat writes that the *Kurze Klassifikation* "was the first work in which the classification of rocks was treated exclusively, the first to divorce the classification of rocks from the classification of minerals" (p. 2). *Gebirgsart,* a significant word in the title as well as the text of the *Kurze Klassifikation*, has been translated as "rock" by Archibald Geikie; as "rock formation" by Laudan and Ospovat, among others; as "type of mountain" by John Greene; as "rock mass" by Ospovat; and as "mountain range" (Alexander M. Ospovat, "Reflections on A. G. Werner's *Kurze Klassifikation*," in *Toward a History of Geology*, ed. Cecil J. Schneer (Cambridge, Mass.: M.I.T. Press, 1969), 251-252). Ospovat explains that a "German miner always speaks of being in a *Gebirge* as soon as he goes below the surface of the earth, whether the surface is mountainous or plain" (Ospovat, 97). When different methods of working were required, the miner had encountered a new *Gebirgsart,* provided that it was an extensive rock mass rather than a single isolated layer. If the same method of working was employed for two separate rock masses, isolated by an extensive intervening rock mass of different character, miners designated them as distinct *Gebirgsarten* regardless of their similar appearance. Ospovat comments that Werner "considered the whole solid earth's crust to be a *Gebirge,* consisting of different parts, or *Gebirgsarten*. Not every rock was a *Gebirgsart,* however, but only those that form sufficiently large or independent units" (Ospovat, 97-98). Miners employed method of work, deposit extent, and location to distinguish *Gebirgsarten*. Werner employed rock texture and structure as analogous to the miners' method of working, and to some degree indicative of age and mode of formation—for Werner, crystal structures indicated a formation during the primitive time period by precipitation in calm, deep water. Regarding the criterion of location, Ospovat comments: "Werner also relied upon the relative position of rocks, considering this the most important clue to the time of the rock's formation. The constituents of the rocks were only secondary considerations. As Werner's student Leopold von Buch put it when he explained the concept *Gebirgsart* to members of the Berlin Academy of Science, in numbering the houses on a street it does not matter what kinds of materials the houses are built of or what their colors are. The only things that matter are whether the various units in that street fulfill the concept house and where the units are located" (Ospovat, 98). This structuralist advice should not be taken as disavowing interest in using structure as the basis for temporal inferences.

[217]Werner, *Kurze Klassifikation,* Section 5, trans. Ospovat, p. 44, 46.

[218]Werner, *Kurze Klassifikation,* Section 19, trans. Ospovat, p. 68.

[219]Werner, *Kurze Klassifikation,* Section 30, trans. Ospovat, p. 78.

[220]Werner, *Kurze Klassifikation,* Section 34, trans. Ospovat, p. 88.

TABLE 11. Werner's Classification of Rock Formations

Type	Epoch	Mode	Description	Examples
Primitive	Earliest	Chemical precipitation from a primeval ocean ("Neptunism")	Located beneath other types of formations; often aggregated; non-fossiliferous; generally nonstratified	13 described, including granite, gneiss, mica–slate [mica–schist], porphyry, primitive limestone, quartz–rock, basalt
Transition	Middle	Combination of chemical and mechanical processes	Werner established this category after the publication of the Kurze Klassifikation	
Flötz	Recent	Formed from products of the mechanical destruction of pre-existing formations	Located above primitive formations; often simple rather than aggregated; often fossiliferous; often stratified	18 described, including flötz limestones, sandstones, coals, chalks, rock salts, gypsums, ironclays
Volcanic	Recent	Rocks formed by subterranean fire	Located in a disorderly manner within other formations; associated with conical mountains, hot springs, and steam vents; found neither with fossils nor metals	pumice, ash, and lavas, sometimes containing crystals
		Rocks altered by subterranean fire	Often stratified; often located above coal formations[a]	porcelain jaspers, columnar clay–ironstone
Alluvial	Most recent	Rivers, surface flooding	Consist of destroyed materials from any kind of formation	gravel, clay, sand, and peat

a. Pseudo–volcanic rocks or "floetz formations [Flötz–Gebirge] which have been altered through earth fires and are probably always coal formations [Steinkohlen–Flötzgebirge], insofar as coal deposits have furnished the material for such fires, they therefore still have nearly the same regular, floetz–like or stratified structure which these formations [Flötzgebirgen] previously had." Werner, Kurze Klassifikation, Section 32, trans. Ospovat, p. 82.

This taxonomy is thoroughly temporal in character: Werner stipulated that the four classes are not sharply distinguished, but rather "grade into one another." Since "the various modes of formation of these rocks, over the *vast period of time* since the beginning of our earth, in most cases *imperceptibly* gave way to one another, it is impossible that such *gradations* should not occur in the rocks themselves."[221] This gradualist perspective was ignored in older polemic characterizations of Werner as a young-Earth catastrophist.

For Werner, universal formations occurred generally in many regions around the Earth and were formed in the primitive ocean during the same period of time, in contrast to "anomalous formations," which were of restricted occurrence and resulted from smaller inundations. Ospovat describes Werner's conception:

> Universal formations are those which extend around the whole globe and can be found in all regions of the earth. They are, however, not necessarily continuous; most of them are interrupted. Werner explained that in some cases the interruptions in the universal formations were caused by the destruction of parts of the formations after their formation, and in other cases the interruptions were there from the beginning because the activities and contents of the universal ocean, even during a particular period, were not everywhere the same.[222]

Because Werner's scheme of Earth history presupposed a gradually-diminishing primeval ocean from which the Primitive formations successively precipitated, followers such as Robert Jameson and John Murray christened Wernerian geognosy as "Neptunism."[223] However, this highly-problematic term soon became loosely applied to practically any scheme of Earth history that either hypothesized a primeval ocean or that regarded most of the Primitive rocks as originating predominantly through the agency of water rather than fire, even if these schemes shared little of the geognost's predilection for evidence from the field rather than the laboratory or library.

Geognostic works span a continuum from descriptive field mineralogy, on the one hand, which was concerned with ordering formations in place according to their structural relations,

[221] Werner, *Kurze Klassifikation,* Section 4, trans. Ospovat, p. 44, emphasis added.

[222] Ospovat, p. 100.

[223] John C. Murray, *A Comparative View of the Huttonian and Neptunian Systems of Geology, in answer to the Illustrations of the Huttonian Theory of the Earth, by Professor Playfair* (Edinburgh, 1802). Neptunism was also used by Jameson; George W. White, "Foreward" to Robert Jameson, *The Wernerian Theory of the Neptunian Origin of Rocks,* ed. Jessie M. Sweet (New York: Hafner Press, 1976), vii. For accurate summaries of Wernerian geognosy see Laudan, *From Mineralogy to Geology,* 88-94; Ospovat, 20-24.

to those more obviously related to Theories of the Earth, on the other hand, concerned with ordering formations in time according to their epoch of origin. Not surprisingly, many works, like the *Kurze Klassifikation* itself, pursued the structural and historical aims of geognosy in combination.

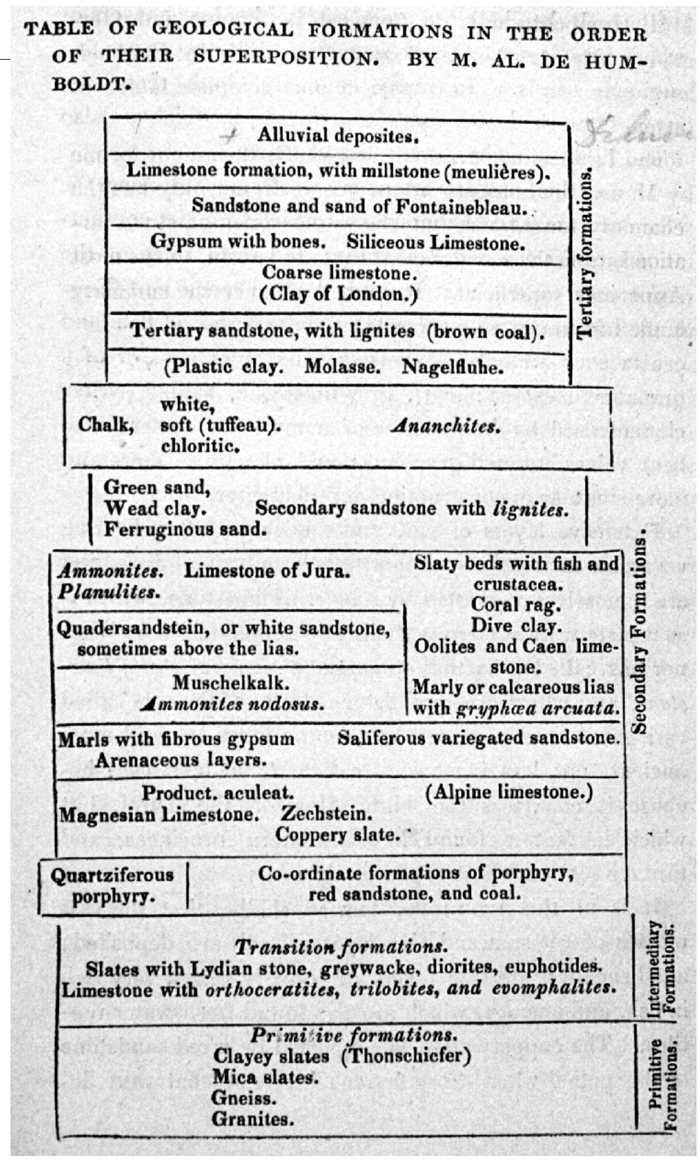

TABLE OF GEOLOGICAL FORMATIONS IN THE ORDER OF THEIR SUPERPOSITION. BY M. AL. DE HUMBOLDT.

Alluvial deposites.	Tertiary formations.
Limestone formation, with millstone (meulières).	Tertiary formations.
Sandstone and sand of Fontainebleau.	Tertiary formations.
Gypsum with bones. Siliceous Limestone.	Tertiary formations.
Coarse limestone. (Clay of London.)	Tertiary formations.
Tertiary sandstone, with lignites (brown coal).	Tertiary formations.
(Plastic clay. Molasse. Nagelfluhe.	Tertiary formations.
Chalk, white, soft (tuffeau). chloritic. *Ananchites.*	
Green sand, Wead clay. Ferruginous sand. Secondary sandstone with *lignites.*	
Ammonites. Limestone of Jura. *Planulites.* / Quadersandstein, or white sandstone, sometimes above the lias. / Muschelkalk. *Ammonites nodosus.* — Slaty beds with fish and crustacea. Coral rag. Dive clay. Oolites and Caen limestone. Marly or calcareous lias with *gryphœa arcuata.*	Secondary Formations.
Marls with fibrous gypsum Arenaceous layers. Saliferous variegated sandstone.	Secondary Formations.
Product. aculeat. Magnesian Limestone. Zechstein. Coppery slate. (Alpine limestone.)	Secondary Formations.
Quartziferous porphyry. — Co-ordinate formations of porphyry, red sandstone, and coal.	Secondary Formations.
Transition formations. Slates with Lydian stone, greywacke, diorites, euphotides. Limestone with *orthoceratites, trilobites, and evomphalites.*	Intermediary Formations.
Primitive formations. Clayey slates (Thonschiefer) Mica slates. Gneiss. Granites.	Primitive Formations.

FIGURE 8. Table of Formations, Alexander von Humboldt, from Cuvier, 1825. HSCI.

For example, consider a table of formations created by Werner's world–traveling student Alexander von Humboldt (Figure 8, which in 1825 was substituted for Cuvier's depiction of the Paris basin, Figure 35 on page 309).[224] It would be false to regard this table of "formations in the order of their superposition" as a description merely of structural relations. On the opening page of his geognostic essay, Humboldt described the Wernerian definition of "formation" as designating

[224]Georges Cuvier, *Discours sur Les Révolutions de la Surface du Globe, et sur les Changemens qu'elles ont Produits dans le Règne Animal*, 3d ed. (Paris, et à Amsterdam: chez G. Dufour et Ed. d'Ocagne, 1825), after p. 294. The table was then included in Georges Cuvier, *Essay on the Theory of the Earth. By Baron G. Cuvier... with Geological Illustrations, by Professor Jameson. Fifth edition, Translated from the last French edition, with Numerous Additions by the Author and Translator* (William Blackwood, Edinburgh; and T. Cadell, Strand, London, 1827), after p. 248.

> an assemblage of mineral masses so intimately connected, that it is supposed they were formed at the same epoch, and that they present, in the most distant parts of the earth, the same general relations, both of composition, and of situation with respect to each other.[225]

In other words, for Humboldt, geognosy uncovers the structural relations between formations in a given region. But this structural aim did not stand on its own; it was inextricably associated with temporal events and historical inferences. Humboldt's expectation that the spatial relations analyzed in a specific place would hold to some degree in distant regions was based on the Neptunist assumption (attributed to Werner) of the contemporaneous origin of a given formation wherever it may occur around the globe: "It is by this isochronism only, this admirable order of succession, we are enabled to observe with certainty."[226] Thus, in a process of

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[225]Alexandre von Humboldt, *A Geognostical Essay on the Superposition of Rocks, in Both Hemispheres* (London: Printed for Longman, Hurst, Rees, Orme, Brown, and Green, 1823), 1. Humboldt drew an extensive contrast between two senses of "formation." First, Humboldt described a genetic, geogonic meaning of "formation," which invokes a causal agent (e.g., subterranean fires). Second, there is a historical (Wernerian or geognostic) meaning of "formation," which describes an assembly of mineral masses and infers that they formed at the same epoch, without specifying physical or chemical causes. "In geognosy, the word formation either denotes the manner in which a rock has been produced, or it designates an assemblage of mineral masses so intimately connected, that it is supposed they were formed at the same epoch, and that they present, in the most distant parts of the earth, the same general relations, both of composition, and of situation with respect to each other. Thus the formation of obsidian and of basalt is attributed to subterraneous fires; and it is also said that the formation of transition clay-slate contains Lydian stone, chiastolite, ampelite, and alternating beds of black limestone, and of porphyry. The first acceptation of the word is the most conformable to the genius of the French language; but it relates to the origin of things, and to an uncertain science founded on geogonic hypotheses. The second acceptation, now generally received by the French mineralogists, has been borrowed from the celebrated school of Werner, and indicates, not what is supposed to have been, but what now exists." This passage is analyzed below, with French text, on page 707.

[226]Humboldt, *Geognostical Essay*, 23. Because of this assumption of isochroneity, Humboldt opposed the use of names for formations that had merely local significance, such as upper limestone, new red sandstone, third formation, etc. Cf. Humboldt's comment: "Werner, in creating geognostic science, has perceived with an admirable sagacity all the relations under which we should view the independence of the primitive, transition, and secondary formations. He has shown what we ought to observe,—what it is important to know; he has prepared, and foreseen in some degree, a part of the discoveries with which, through him, geognosy has been enriched in countries which he could not visit. As formations do not follow the variations of latitude and climate, and phenomena, observed perhaps for the first time in the Himalaya, or the Andes, are found again, and often with an association of circumstances that seem to be entirely accidental, in Germany, Scotland, or the Pyrenees, a very small portion of the globe, a territory of some square leagues in which nature has assembled many formations, may, (like a true microcosm of the ancient philosophers), give rise, in the mind of an excellent observer, to very accurate ideas on the fundamental truths of geognosy. In fact, the first views of Werner, even those which that illustrious man had formed before the year 1790, possessed a justness that is still remarkable. The learned of every country, even those who show no predilection for the school of Freiberg, have preserved them as the basis of geognostic classifications; and yet what was known, however, in 1790, of primitive, transition, and secondary formations, was founded almost entirely on Thuringia, on the metalliferous mountains of Saxony, and those of the Harz, on an extent of country not 75 leagues in length." Humboldt, *Geognostical Essay*, 80–81. Compare Phillips similar assessment in footnote 183 on page 352; contrast Lyell's rhetoric about Werner's limited travels on page 331.

analysis and synthesis (summarized in Table 12), the present-day observations of the geognost in the field (rather than the causal hypotheses of a physical or chemical geogonist) provided a basis for the reconstruction of a sequence of contingent historical events, events which in turn were used to explain the consistent patterns (or lawlike regularity) of geognostic observations in distant places.[227]

TABLE 12. Temporal Aspect of the Structure of Geognostical Inference

	Analysis	Conclusion of Analysis Premise of Synthesis	**Synthesis**
Step:	Present-day field observations in a restricted area	Reconstruction of a sequence of historical events	Explanation of present-day field observations in a distant region, to which the same events extended
Description:	structural, non-causal inference	temporal, contingent pattern	lawlike regularities embodied in a table of 40 universal formations

For these reasons, although technical geognostical works and textual Theories of the Earth were not coextensive, they did overlap considerably, and the boundary between structural geognosy emphasizing descriptive mineralogy and historical geognosy invoking a Theory of the Earth was often indistinct. Geognostical works sometimes began with extensive reviews of Theories of the Earth, such as the "Discours préliminaire" of D'Aubuisson's *Traité de Géognosie* (1819).[228] Going further, however, many writers, both friendly and hostile, regarded geognostical works as embodiments of Wernerian claims regarding the epoch of origin of rock formations which in their view amounted to a Theory of the Earth. Some of

[227] This preliminary summary of the aims and character of geognosy is contested. Recent debates over whether the works of Werner and Wernerians were truly "historical" are analyzed below, beginning on page 705. The historical component of geognosy contrasts markedly with the aims of many English Theorists such as John Strachey and William Smith who, despite sharing some stratigraphical techniques with geognosts, nevertheless held to ahistorical explanations of the structural relations of strata; cf. page 661ff. Cf. Kitts's description of the patterns of events discovered by historical geologists, in footnote 77 on page 41.

[228] Jean François D'Aubuisson de Voisins, *Traité de Géognosie, ou exposé des connaissances actuelles sur la constitution physique et minerale du globe terrestre,* 2 vols. (Strasbourg; Paris: F. G. Levrault, Éditeur, 1819).

Werner's most sympathetic students, including Robert Jameson, regarded Werner's work as embracing and conveying a Theory of the Earth.[229] Critics included William Thomas Brande (1788–1866) who commented in 1817, after reviewing various Theories of the Earth, that the "prevailing theories of the present day… are the inventions of Professor Werner, of Freyburgh [*sic*], and Dr. Hutton, of Edinburgh."[230]

It is not unusual to find, in works that were allegedly purely factual in character, that the investigator's allegiance to a Theory of the Earth was expressed in the choice of descriptive ("factual") terminology such as "primitive formation." Indeed, Werner explicitly preferred the designation "Primitive" to other terms because of the implied temporal reference.[231] The nineteenth-century geologist Henry Thomas de la Beche (1796–1855) lamented:

> How long have geologists seen through the theoretical medium of the divisions, primitive, transition, secondary, and tertiary? It was taken for granted that these divisions were applicable to the whole surface of the globe; descriptions were always made with reference to them; and the consequence is, that there is now much difficulty in discovering what is valuable in such descriptions, particularly when countries, distant from those where these divisions were first imagined, have been examined.[232]

Descriptive natural history was not always disjoined from theoretical debates in the Theory of the Earth tradition. The case of Wernerian geognosy illustrates that intense debates over Theories of the Earth could take the form of dry and descriptive fieldwork employing incompatible systems of nomenclature and mineral classification. More fundamentally, specific technical practices were developed and mobilized in emerging technical traditions tacitly to

[229]This remains true despite the fact that Jameson distinguished the geognosy of Werner from chemical and physical geogonic hypotheses, repudiating the latter with language similar to that later employed by Humboldt (quoted above); see page 319.

[230]William Thomas Brande, *Outlines of Geology; being the substance of a course of lectures delivered in the theatre of the Royal Institution in the year 1816* (London: J. Murray, 1817), as quoted in Horace B. Woodward, *The History of the Geological Society of London* (Burlington House, London: Geological Society, 1907), 85.

[231]Werner, *Kurze Klassifikation,* Section 5, trans. Ospovat, p. 44, 46. Compare the previous discussion of the theoretical character of descriptive geology, page 35ff.

[232]Henry Thomas de la Beche, *Sections and Views Illustrative of Geological Phenomena* (London: Treuttel & Würtz, 1830), iv. The same point could be made for other descriptive terms, including "diluvial deposit," "crater of elevation," "diminution of the sea," etc.

extend positions which remained subject to explicit multi-disciplinary debate within Theories of the Earth.

§ 4-ii-e. Cosmogony

Cosmogony and *cosmogeny* were other names for the tradition used synonymously with "Theory of the Earth" by many writers.[233] One example is Philip Howard's work with the following title, published in 1797:

> Thoughts on the Structure of This Globe: The Scriptural History of the Earth and of Mankind, compared with the Cosmogonies, Chronologies, and Original Traditions of Ancient Nations; an Abstract and Review of Several Modern Systems; with An Attempt to Explain Philosophically, the Mosaical Account of the Creation and Deluge, and to deduce from this last Event the Causes of the Actual Structure of the Earth, in a series of letters with notes and illustrations.[234]

At the turn of the nineteenth century cosmogonies—particularly eternalistic and materialistic ones—were sometimes regarded as not only misguided but subversive; opposition was often motivated by religious and political concerns. Lurking behind many nineteenth-century denunciations of cosmological systems were the by then notoriously outdated Theories of Whiston and Buffon as well as Laplace's more recent nebular hypothesis. The cosmologies of the two latter writers were often discussed in tandem with their alleged implications for religion and politics, particularly in view of circumstances in France, so that wholesale condemnation of cosmological systems (Philip Howard notwithstanding) could serve as the rhetorical equivalent of proclaiming religious and political innocence.[235] Howard's Theory was first published in French in 1786, occasioned by a difference of opinion between Howard and the Marquis de Montigny during a joint tour of Switzerland (the latter was fond both of the sys-

[233] The suffixes "-geny" and "-gony" were used interchangeably to refer to processes of the formation or origin of a body, deriving from the nouns γενεά (birth, generation, descent) and γονή (birth, seed, descendant). The prefix "cosmo-," on the other hand, generates many ambiguities explored in this section.

[234] London: Printed for R. Faulder, 1797.

[235] Cf. J. B. Morrell, "Professors Robison and Playfair, and the Theophobia Gallica: Natural Philosophy, Religion, and Politics in Edinburgh, 1789–1815," *Notes and Records of the Royal Society of London* 26 (1971): 43–64.

tem of Buffon and of radical theories of government). With chapters on Wallerius, Hutton and Moses, Howard's Theory in part sought to defend Christianity from such systems, and toward the same end the English edition was considerably enlarged.[236]

James Hutton provides a different example of the synonymous usage of cosmogony and Theory of the Earth. After compiling particular observations regarding the extent of coastline erosion, Hutton suggested that Britain and Norway were once connected by dry land. Hutton touted this extrapolation of landform observations as "a step in our cosmogeny" which "illustrates the theory of the earth."[237] Hutton's example is interesting because some writers, such as Lyell, employed cosmogony in a deprecatory sense as antithetical to natural knowledge based on field observations. Despite the usage represented by Hutton, critics of the tradition who preferred fieldwork to arguments from textual evidence and mathematical astronomy co-opted *cosmogony* to denigrate Theories of the Earth as an endeavor allegedly characterized by the absence of observation, or at least by the absence of observations of the right kind. Even Hutton himself was unjustly caricatured as an armchair Theorist who avoided fieldwork.[238]

Cosmogony was a preferred term used by Charles Lyell and many later critics to characterize the tradition as a predominantly cosmological endeavor opposed to a purely geological science, implying that the latter would respect the integrity of the Earth and rule out non-terrestrial considerations (e.g., comet impacts, origin of solar system, changes in the Sun). Ironically, however, this usage was initiated by Theorists themselves, a fact of great interest for the differentiation of Theories of the Earth and the emergence of technical disciplines. In the late eighteenth century, Theorist Jean André Deluc (1727–1817) proposed the word *geology* as an

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236 Philip Howard, *Lettres d'un Voyageur sur les Causes de la Structure Actuelle de la Terre* (Strasbourg: Chez Levrault, 1786). The French edition is incorrectly attributed to a John Howard in William B. Ashworth, Jr. and Bruce Bradley, *Theories of the Earth, 1644–1830: The History of a Genre* (Kansas City, Missouri: Linda Hall Library, 1984), 60 (catalog number 82). Bruce Bradley traced the misattribution to A. A. Barbier, *Ouvrages anonymes,* II: 1245 (personal communication).

237 James Hutton, *Theory of the Earth, with Proofs and Illustrations,* 2 vols. (Edinburgh: for Cadell and Davies, London, 1795), 1: 286.

238 On Hutton's fieldwork see footnote 21 on page 274.

alternative to cosmogony precisely in order to distinguish the more geological Theories of the Earth from those which put a greater emphasis on cosmology. This usage was followed by other Theorists, including Noël André (1728–1808) who mentioned "Géologie" in the first sentence of his "Discours préliminaire."[239]

In her classic study *Cosmogonies of our Fathers,* Katharine Brownell Collier surveyed the views of a variety of Theorists before Deluc, ironically placing Deluc in the company of cosmogonists as diverse as Descartes, Robert Fludd, Athanasius Kircher, Thomas Burnet, John Ray, Gottfried Wilhelm Leibniz, William Whiston, John Woodward, Nehemiah Grew, William Derham and Buffon, among others.[240] Deluc's attempt to demarcate between cosmological Theories of the Earth and those with a more geological character such as his own was no merely antiquarian exercise; cosmological and cosmogonical Theories of the Earth were still being written and continued to be published well into the nineteenth century. For example, one among many nineteenth-century cosmological Theories of the Earth was that of John Hay, *Calculations Introductory to a New Theory of the Earth* (Edinburgh, 1824), a rather unoriginal and obscure Theory accurately summarized in ten plates (reproduced as Figure 9 on page 129 through Figure 18 on page 138).[241] The cosmological character of Hay's Theory is evident from all of the diagrams, which indicate that Hay sought a generalized, universal

[239]Deluc wrote: "Je n'entends ici par Cosmologie que la connoissance de la Terre, & non celle de l'Univers. Dans ce sens, Geologie eût été le mot propre; mais je n'ose m'en servir, parce qu'il n'est pas usité. J'employerai donc toujours ce mot Cosmologie, dans le sens que je viens de définir, & par analogie à Cosmographie, & à Cosmopolite surtout, dont on ne se sert que rélativement à la Terre." Jean André Deluc. *Lettres Physiques et Morales sur les Montagnes et sur l'Histoire de la Terre et de l'Homme: Addressées à la Reine de la Grande Bretagne*. The Hague: Chez De Tune, 1778, vii-viii, note (a). See Dennis R. Dean, "The Word 'Geology'," *Annals of Science* 36 (1979): 35–43. Cf. Noël André, *Théorie de la Surface Actuelle de la Terre, Ou plutôt Recherches impartiales sur le temps et l'agent de l'arrangement actuel de la surface de la terre, fondées, uniquement, sur les faits, san système et sans hypothèse* (Paris: A la Société Typographique, 1806).

[240]Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries* (New York: Columbia University Press, 1934; reprinted New York: Octagon Books, 1968). Hereafter, "Collier, *Cosmogonies*."

[241]John Hay, *Calculations Introductory to a New Theory of the Earth, Illustrated with Ten Lithographic Plates: Showing, by principles entirely original, that the sacred account of creation is in harmony with natural results; and, in particular, illustrative of the difficulties that occur in accounting for the original formation of the earth, and its constitutional appearances upon principles hitherto known. Of the earth's original formation. Of the original formation of strata. Of the origin of fissures. Of the formation of mountains. Of the formation of the bed of the ocean. Of the origin of rivers. Of volcanoes, &c., &c* (Edinburgh: Printed for the Author, 1824). Hereafter "Hay, *New Theory.*"

Theory fully integrating cosmology and terrestrial origins. It is worth noting that the unexceptional character of Hay's work belies some traditional generalizations about cosmogonical Theories of the Earth. First, although openly textual in its respectful evaluation of biblical evidence and thoroughly cosmological in orientation, Hay's Theory emphasized the significance of the creation week rather than Noah's flood. For example, Hay's first eight figures all depict occasions before the conclusion to the third day, a manifest reflection of his belief that the first difficulty of a Theory is to determine "The natural cause by which the waters came to be divided from the dry land," a problem posed by centuries of hexameral commentary on the third day.[242] Second, given his premise that the primary cosmological agent was the Sun, it follows as no surprise that Hay envisioned a major role for igneous agency in the formation of the Earth's crust rather than being exclusively Neptunist. In these two respects, this obscure native of Edinburgh was not alone, as we shall see.

In England itself, at any rate, wrested away from its original usage, Deluc's new term was quickly transposed into a contrary discursive context. After the establishment of the Geological Society of London in 1807, *geology* began more and more to refer to the practices of stratigraphical correlation, particularly of Secondary and Tertiary strata, rather than to systems or Theories of the Earth, even those with a more geological character such as Deluc's.

The formation of geology as a discipline distinct from Theories of the Earth deserves further study in light of the rhetorical usage of cosmogony and geology. However, it is clear that from the beginning the word *cosmogony* harbored numerous ambiguities, not the least of which is that *cosmos*, like its equivalents *mundus* and *world,* may refer either to (1) the universe as a whole, (2) the solar system, (3) another planet, (4) the Earth itself, or (5) a particular area

[242] Hay, *New Theory,* 4. In a series of articles Manfred Büttner explores various theological influences upon the structure of early modern geography, including the hexameral theme of the separation of the dry land and the sea; see Manfred Büttner "The Significance of the Reformation for the Reorientation of Geography in Lutheran Germany," *History of Science* 17 (1979): 139–169; Manfred Büttner and Karl H. Burmeister, "Sebastian Münster, 1488–1552," *Biobibliographical Studies* 3 (1977): 99–106; Manfred Büttner, "Philipp Melanchthon, 1497–1560," *Biobibliographical Studies* 3 (1977): 93–97; Manfred Büttner, "Bartholomäus Keckermann, 1572–1609," *Biobibliographical Studies* 2 (1977): 73–79; and Manfred Büttner, "Kant and the Physico-Theological Consideration of the Geographical Facts," *Organon* 11 (1975): 231–249.

of inhabited dry land.[243] In 1699 Thomas Beverley complained of Johan Eisenschmidt's "ambiguous use of words," citing as an example: "When he speaks of the Origin and Formation of the World, he does not tell us what he means by that word: whether the great Compound of the Universe, or that small part only where we reside."[244] Theorists did not always mean the same thing with the same word, even when their views were as similar as Hutton's and Lyell's.

[243]An analogous point regarding so-called "cosmogonic sections" is made on page 371.

[244]Thomas Beverley, *Reflections upon the Theory of the Earth, Occasion'd by a Late Examination of It* (London: W. Kettilby, 1699), 61-62. Cf. Johan Caspian Eisenschmidt, "Diatribe de figura Telluris elliptico-sphaeroide," *Acta Eruditorum* (1691): 315–316. Eisenschmidt supported Burnet on the figure of the Earth, although John Keill used his data rather to confirm the Newtonian figure of the Earth; John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698), 139.

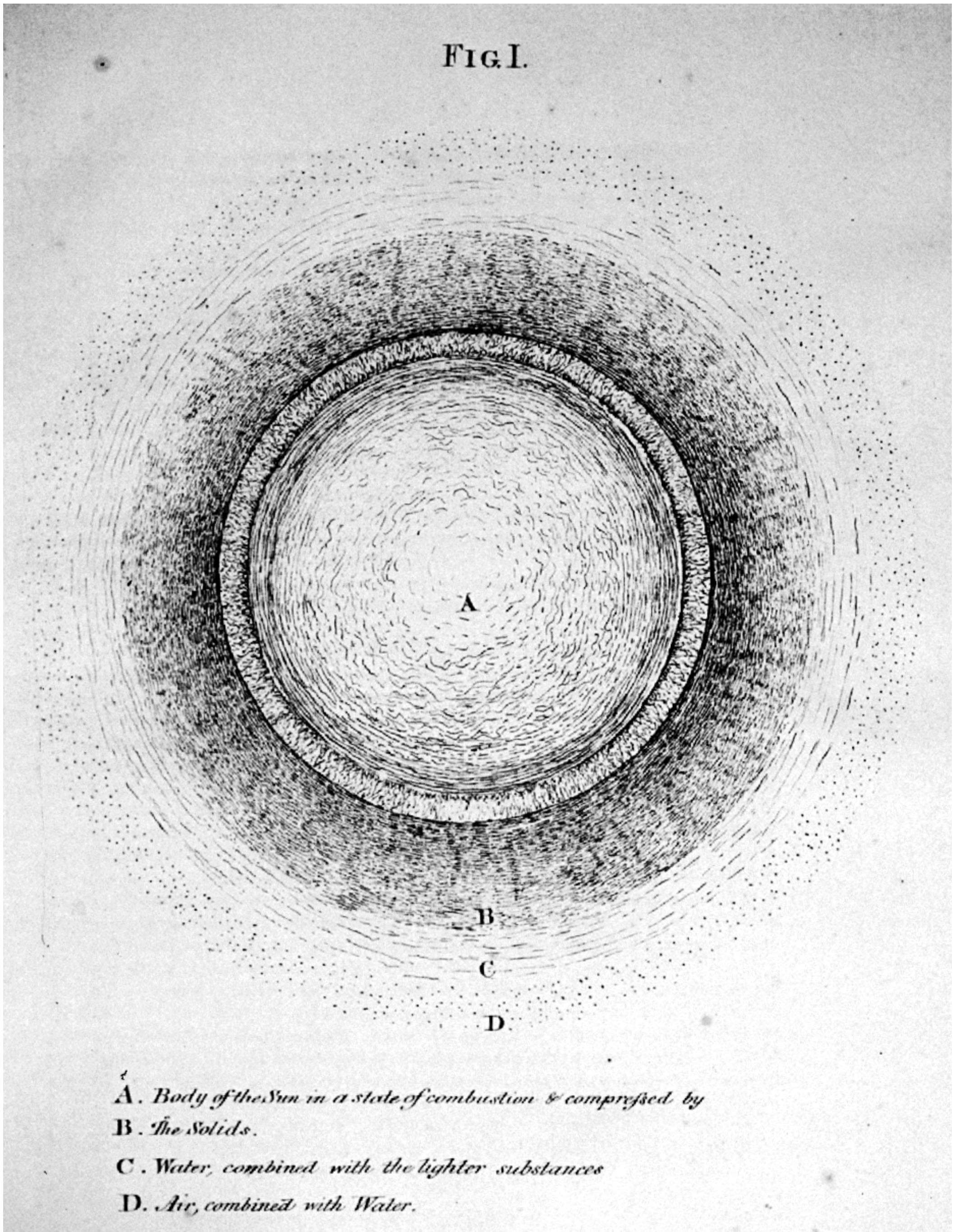

FIGURE 9. John Hay, *Fig. I, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "A. Body of the Sun in a state of combustion & compressed by B. The Solids. C. Water, combined with the lighter substances. D. Air, combined with Water."

Explanation. The matter that now composes the planets derives from the Sun, where it originally consolidated (region B).

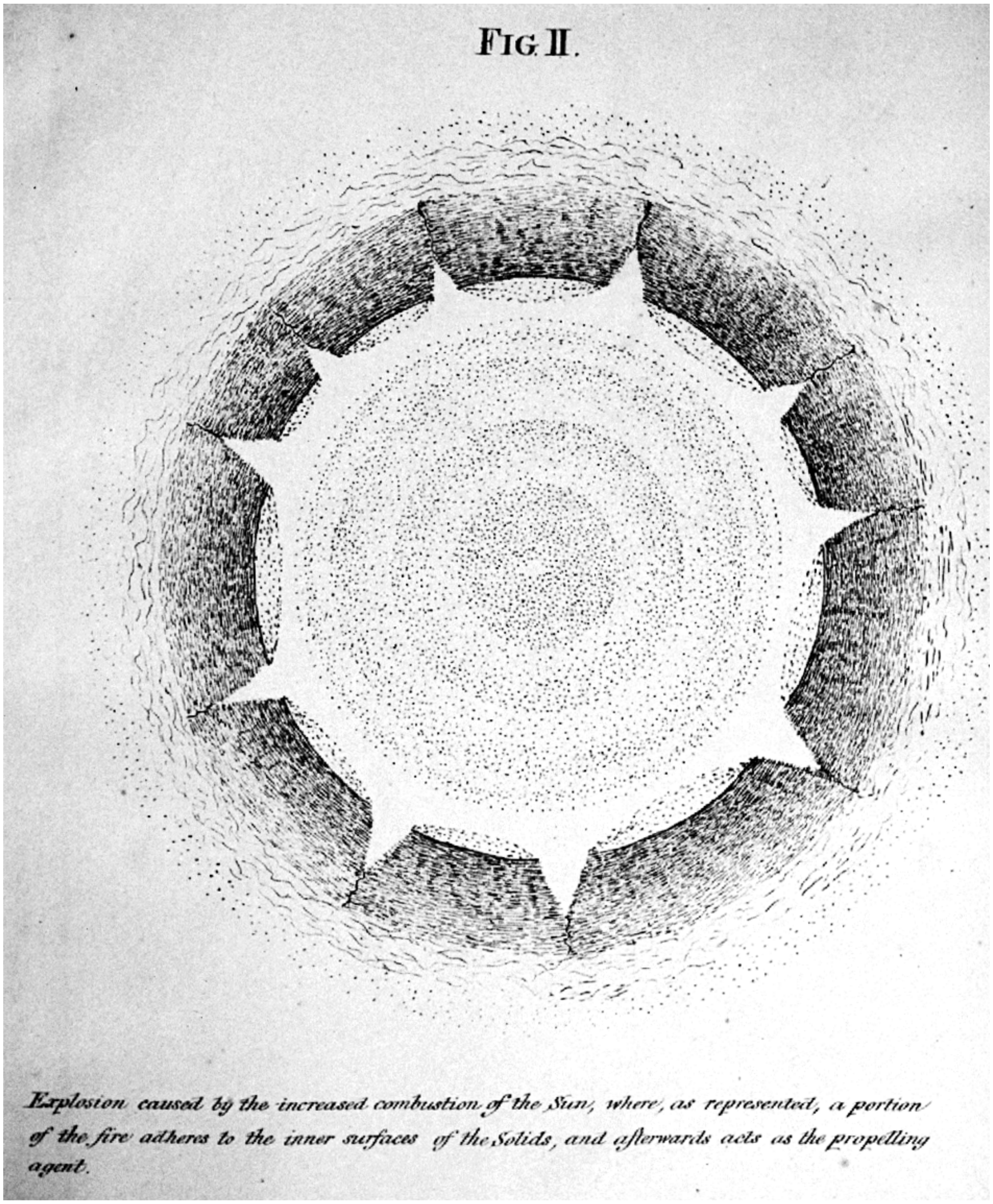

FIGURE 10. John Hay, *Fig. II, New Theory of the Earth* (Edinburgh, 1824), LH.

Explanation. Eventually the solid crust of the Sun exploded due to pressure from the fire beneath.

Caption. "Explosion caused by the increased combustion of the Sun, where, as represented, a portion of the fire adheres to the inner surfaces of the Solids, and afterwards acts as the propelling agent."

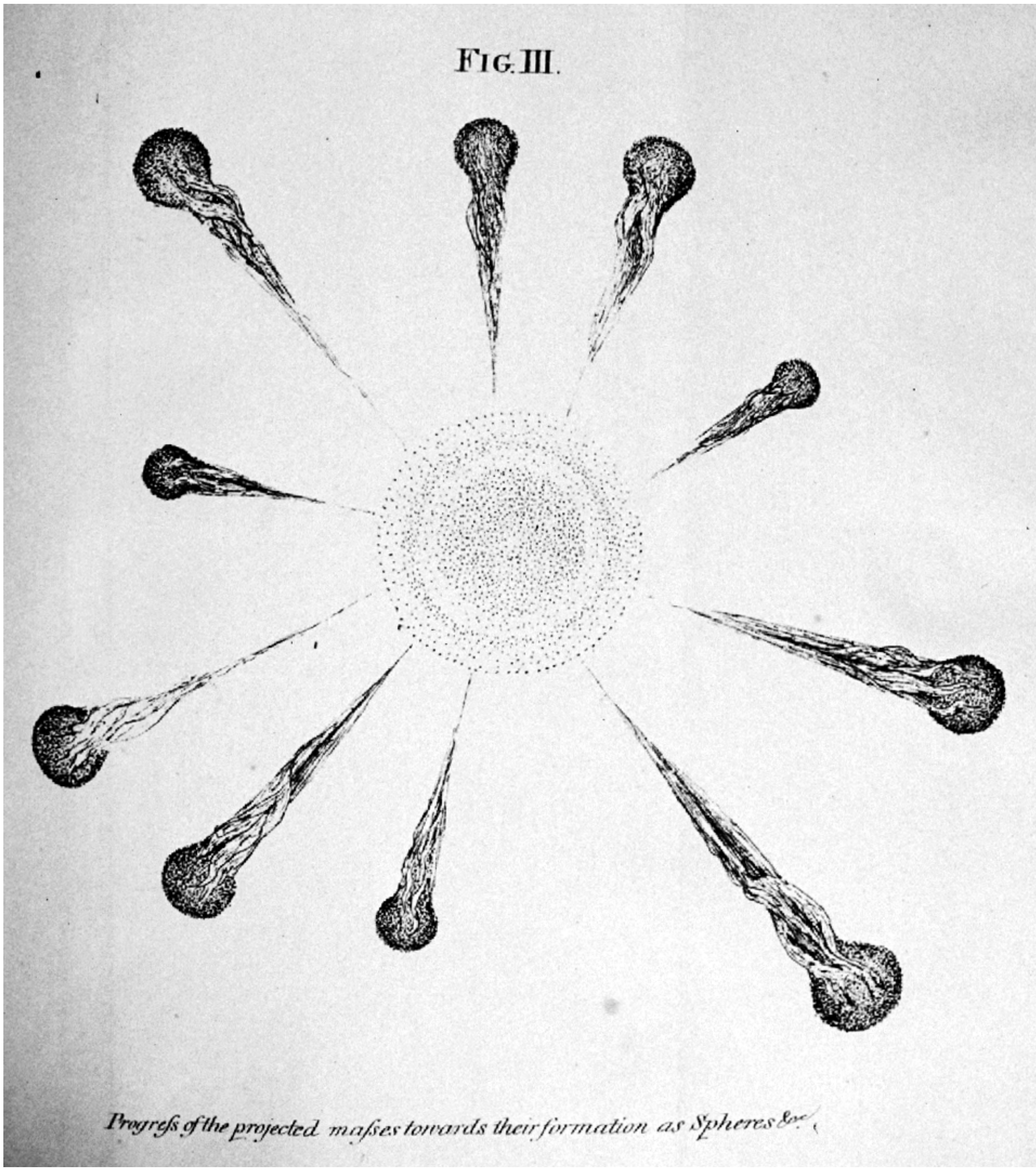

FIGURE 11. John Hay, *Fig. III, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Progress of the projected masses towards their formation as Spheres."

Explanation. The formation of the Earth is part of a cosmogony, or planetary science, encompassing the origin of the entire solar system from the primordial Sun. The origin of the Earth is due to the same processes also at work in the formation of other planets.

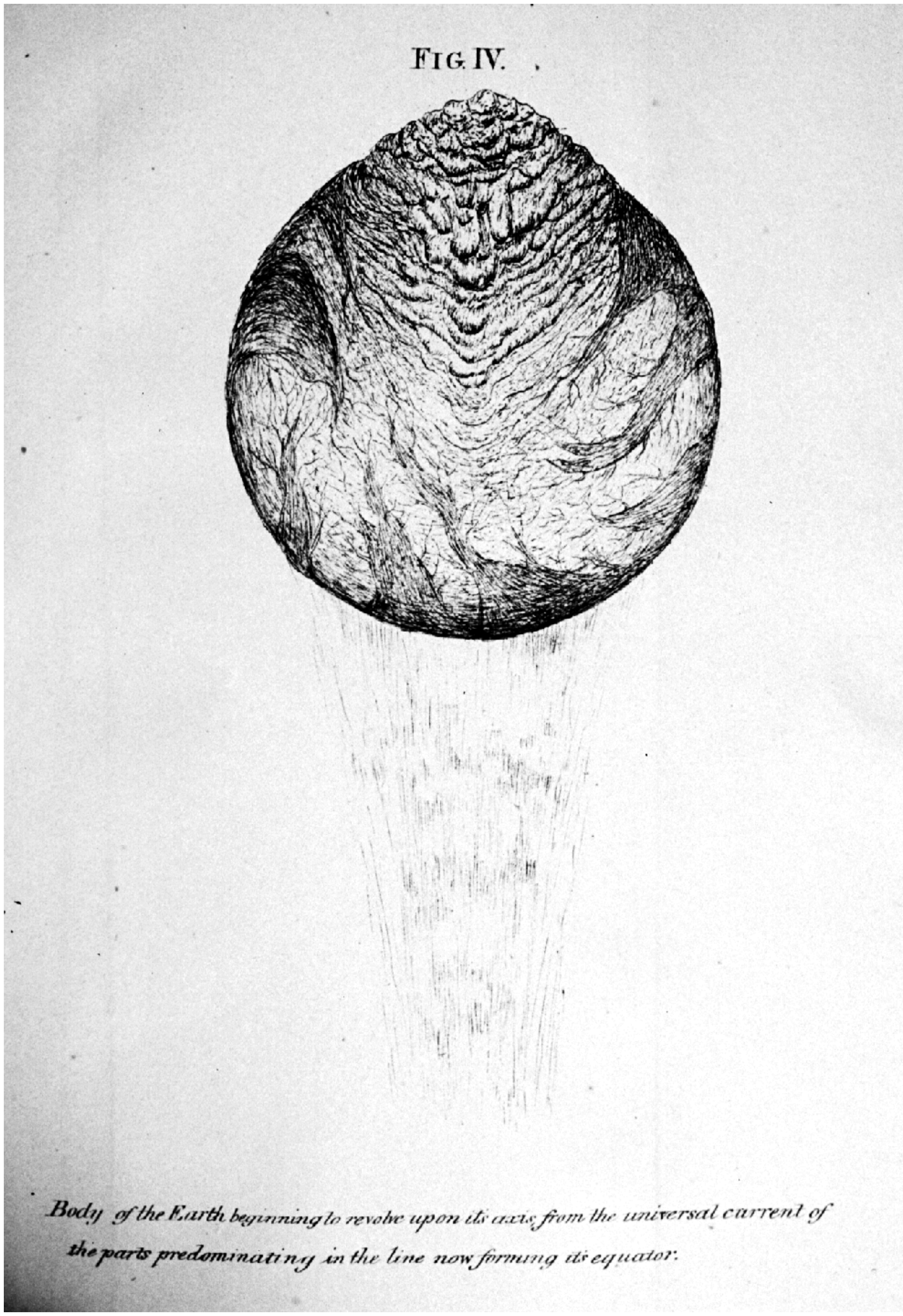

FIGURE 12. John Hay, *Fig. IV, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Body of the Earth beginning to revolve upon its axis from the universal current of the parts predominating in the line now forming the equator."

Explanation. As the Earth consolidated into a rotating body, Hay suggested that "the horizontal strata formed by the declining portion might happen to be deeper upon the equator than at the poles."

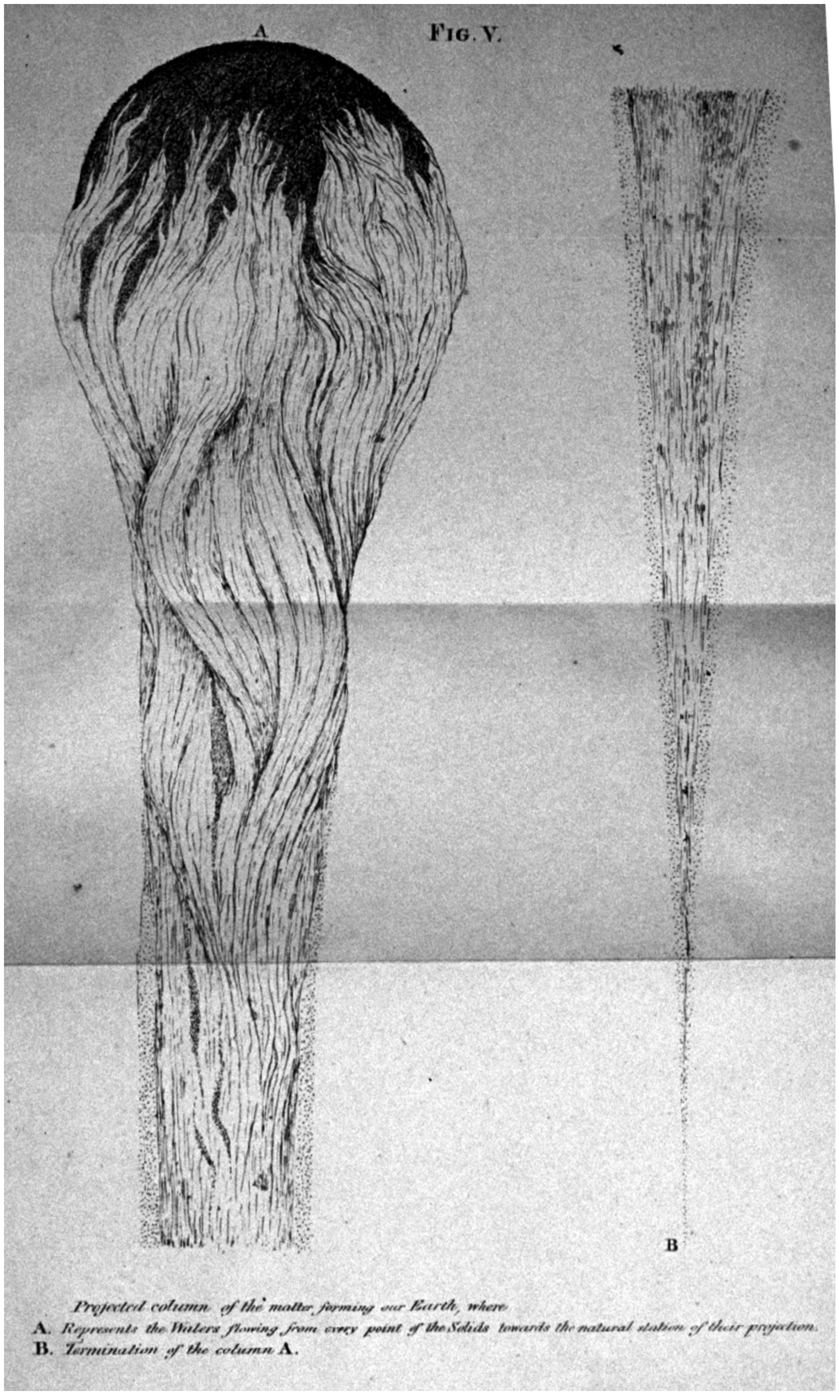

FIGURE 13. John Hay, *Fig. V* (Fold-out), *New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Projected column of the matter forming our Earth, where A. Represents the Waters flowing from every point of the Solids towards the natural station of their projection. B. Termination of the column A."

Explanation. In the primordial Earth, the various types of matter sort out according to their densities.

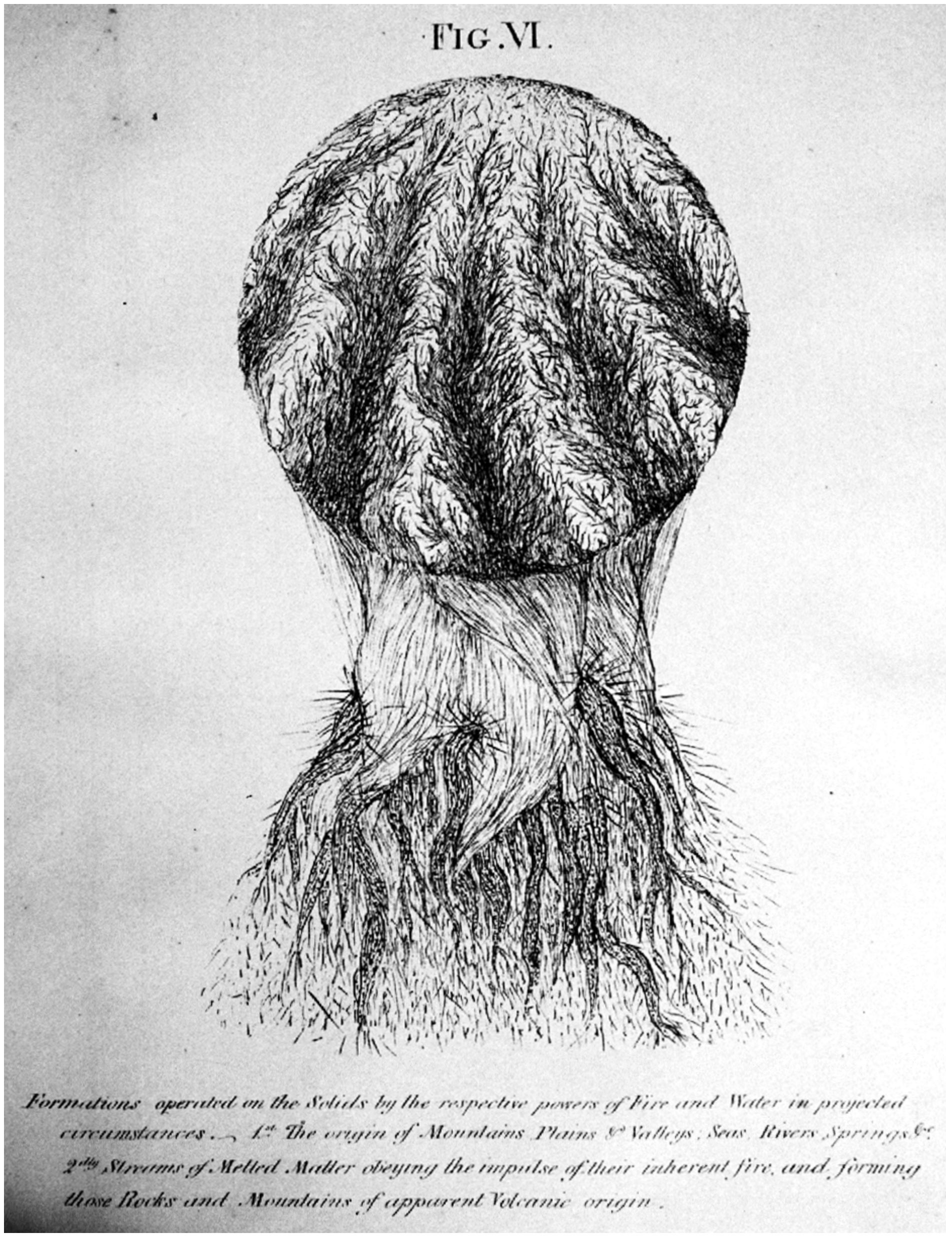

FIGURE 14. John Hay, *Fig. VI, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Formations operated on the Solids by the respective powers of Fire and Water in projected circumstances. 1st The origin of Mountains Plains & Valleys; Seas, Rivers, Springs. 2dly Streams of Melted Matter obeying the impulse of their inherent fire, and forming those Rocks and Mountains of apparent Volcanic origin."

Explanation. By disengaging itself from solids, water sculpted out ocean basins and mountains during "successive universal sweeps." Some mountains formed by fire, underneath other rocks, with inclined strata. Hay thus reconciled Neptunist processes with a Vulcanist or Plutonist cosmogony.

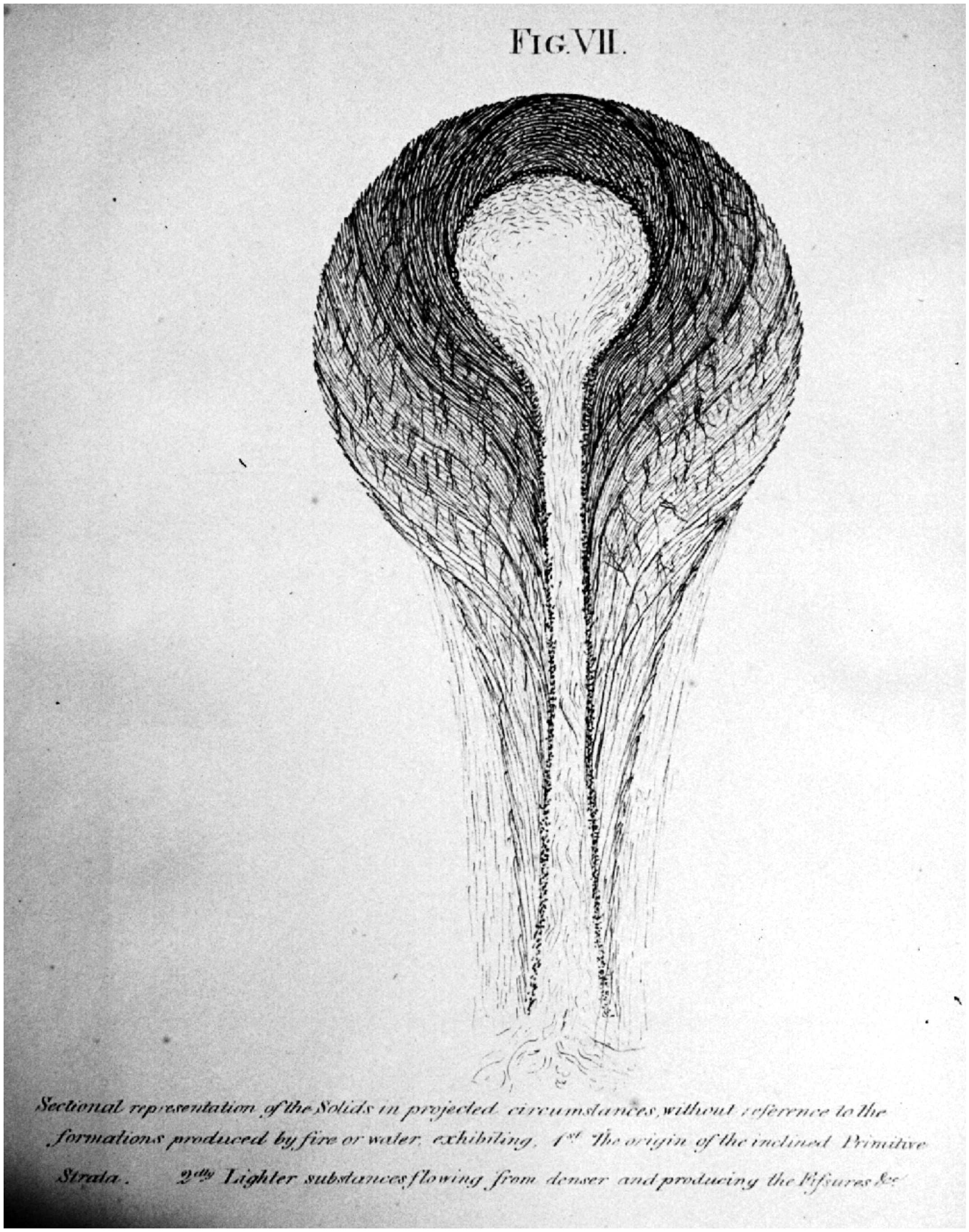

FIGURE 15. John Hay, *Fig. VII, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Sectional representation of the Solids in projected circumstances, without reference to the formations produced by fire or water, exhibiting, 1st The origin of the inclined Primitive Strata. 2dly Lighter substances flowing from denser and producing the Fissures &c."

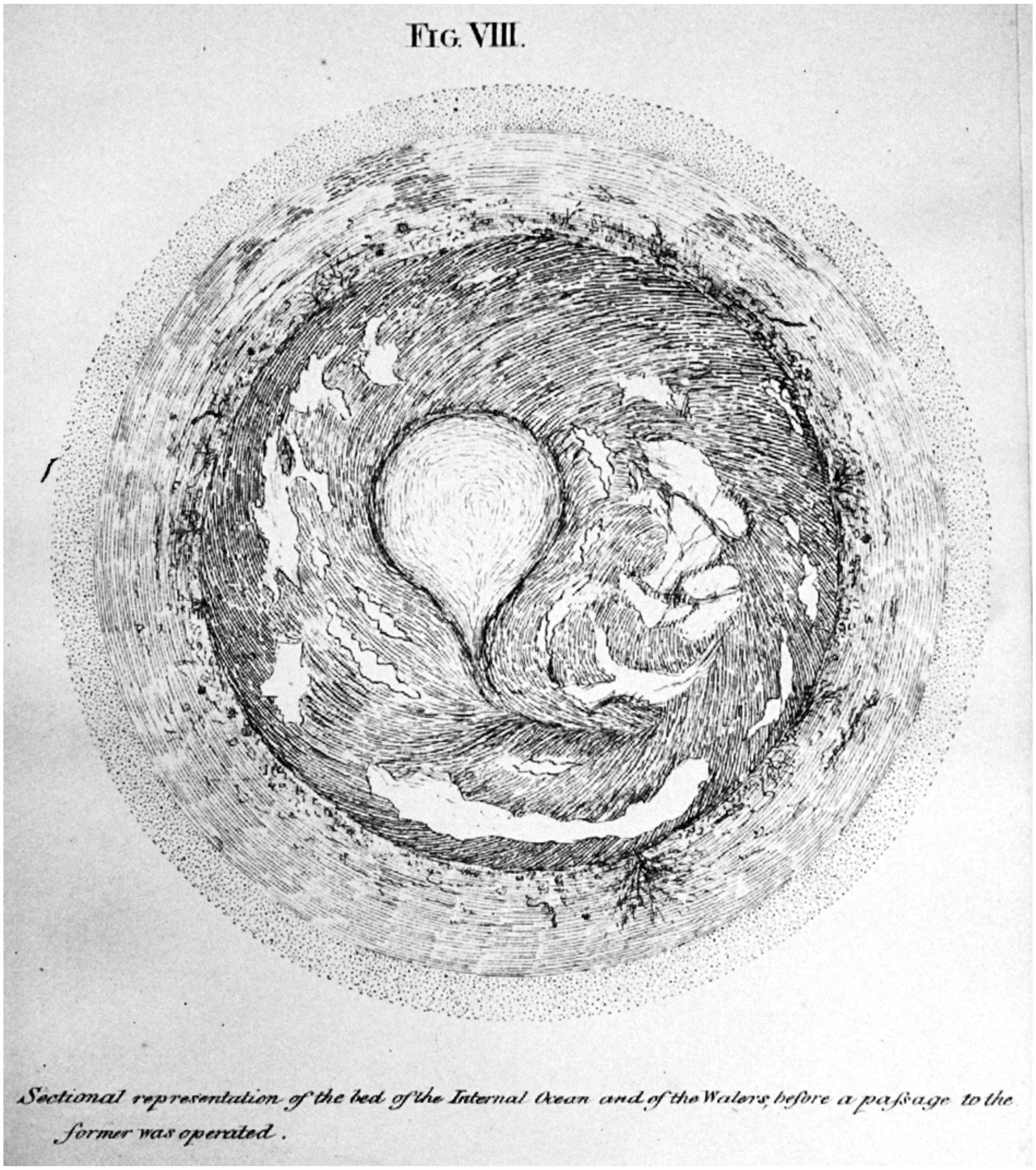

FIGURE 16. John Hay, *Fig. VIII, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Sectional representation of the bed of the Internal Ocean and of the Waters before a passage to the former was operated."

Explanation. Hay's engravings have shifted focus away from the exploding Sun depicted in the early plates to the Earth here consolidated as a globe. When a passageway from the core to the surface was opened, Hay supposed that waters gradually left the external areas and drained into the internal sea; this occurred on the third day of the Creation week according to Genesis 1.9.

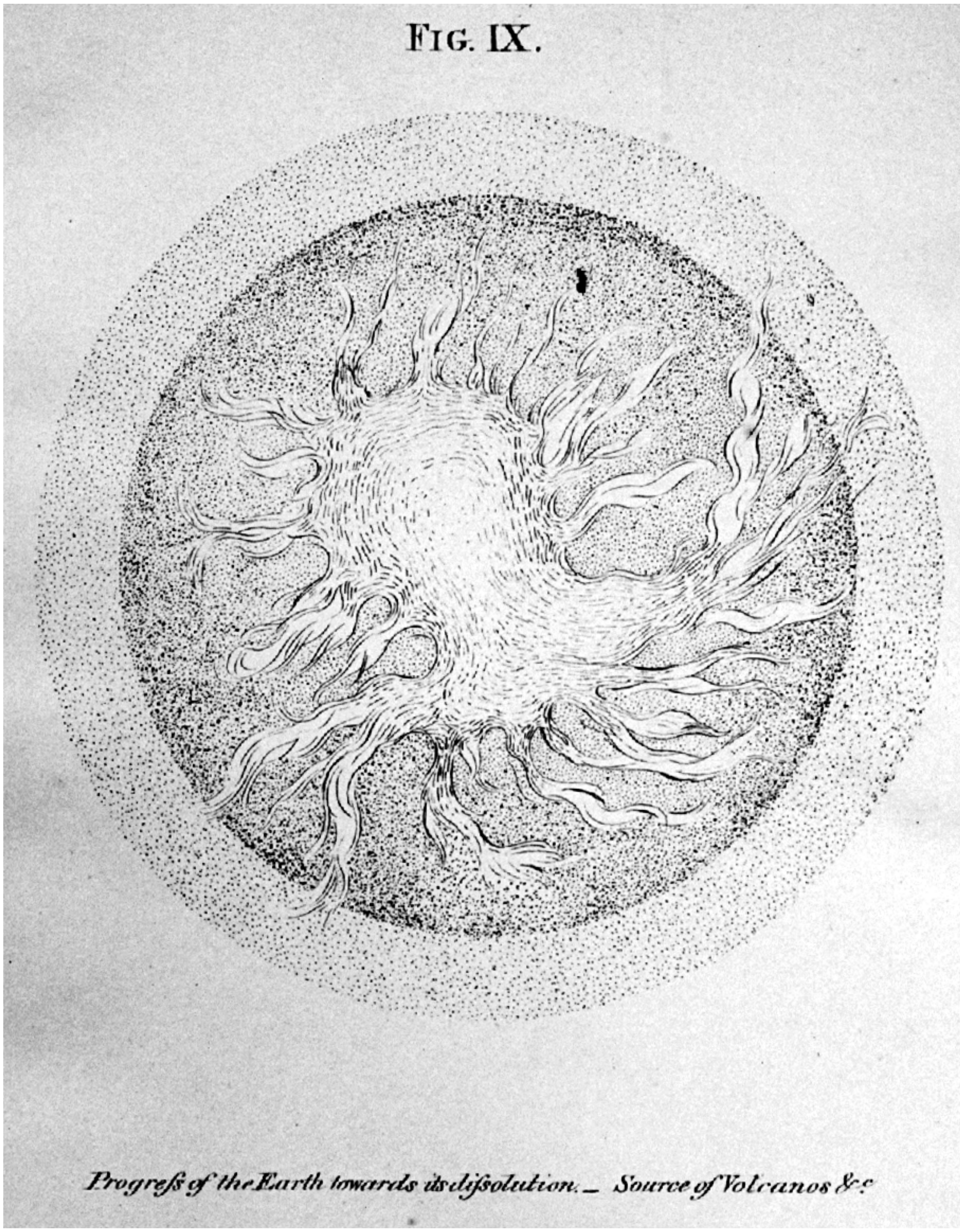

FIGURE 17. John Hay, *Fig. IX, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "Progress of the Earth towards its dissolution.— Source of Volcanos &c."

Explanation. The action of the Sun upon the Earth was enhanced by the departure of water from the surface. The internal fire correlates with the proclamation "let there be light," when darkness covered the face of the deep. Hay concluded: "Thus originating in a single event [explosion of the primordial Sun], not only the establishment of the whole planetary system as it stands, but also of all those peculiar arrangements and appearances by which the constitution of the globe we inhabit is rendered remarkable." Hay, *New Theory,* 9.

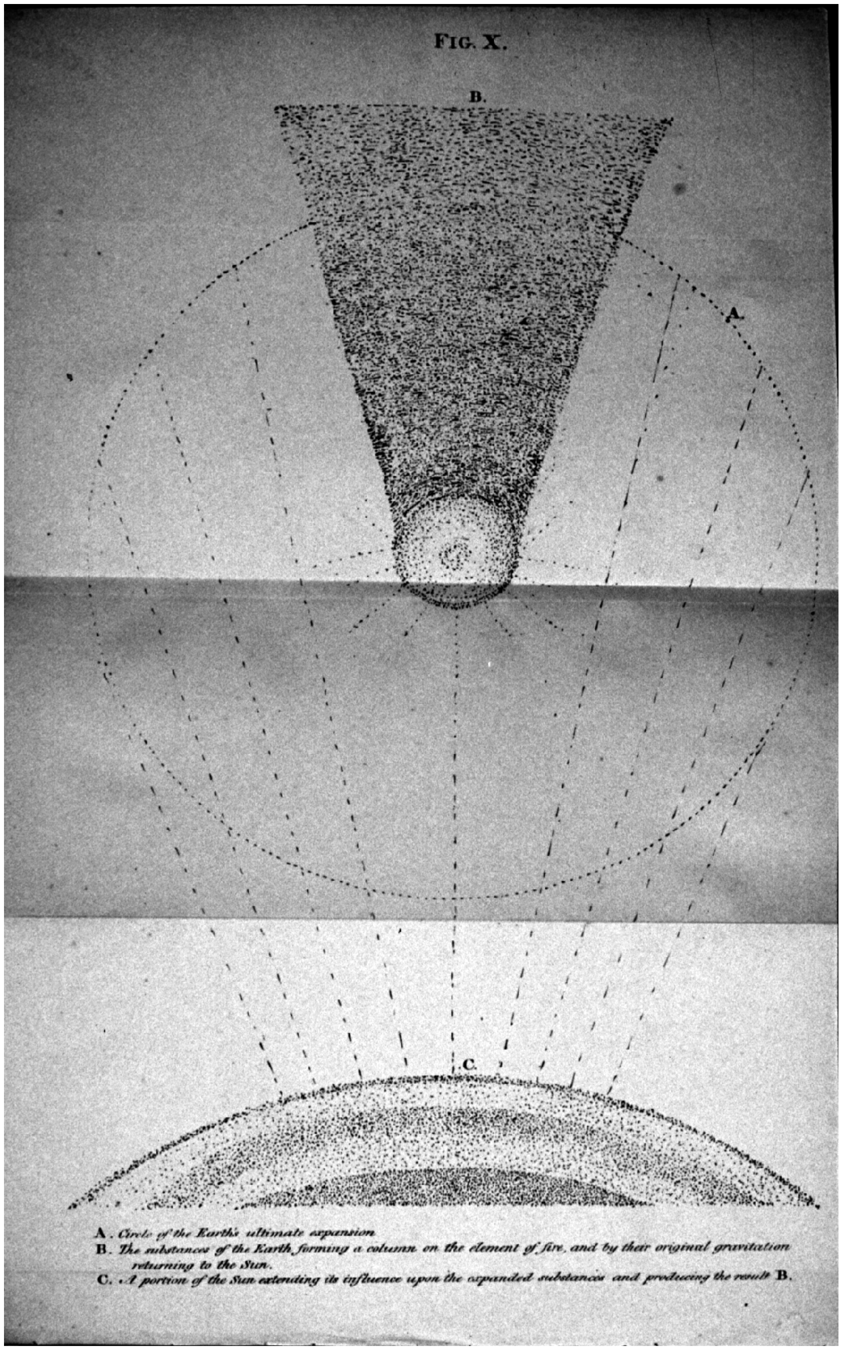

FIGURE 18. John Hay, *Fig. X, New Theory of the Earth* (Edinburgh, 1824), LH.

Caption. "A. Circle of the Earth's ultimate expansion. B. The substances of the Earth forming a column on the element of fire, and by their original gravitation returning to the Sun. C. A portion of the Sun extending its influence upon the expanded substances and producing the result B."

Explanation. Hay's series of sections concluded with a representation of the Earth at the end of the creation week.

§ 5. Textual Criterion 2: Participation in a Common Debate

The first textual criterion, internal attribution (Table 10 on page 106), is insufficient. Many well-known Theories were not listed in Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101, and have not yet been mentioned in considering synonymous phrases. For example, when in "Preuves de la Théorie de la Terre" Buffon surveyed previous systems of the Earth, among the Theories already noted of Burnet, Whiston, Woodward and Bourguet, Buffon also reviewed the works of Leibniz, Scheuchzer, Steno, and John Ray.[245] Taking into account evidence like this, a few examples of additional works which were universally regarded as Theories of the Earth include:

- John Ray (1627–1705), *Three Physico-Theological Discourses,* 1693.[246]
- Alexander Catcott (1725–1779), *Treatise on the Deluge,* 1768.[247]
- Peter Simon Pallas (1747–1811); *Observations sur la formation des montagnes et les changemens arrivés au Globe,* 1777.[248]
- John Whitehurst (1713–1788); *An Inquiry into the Original State and Formation of the Earth,* 1778.[249]
- Richard Kirwan (1733–1812), *Geological Essays,* 1799.[250]

These works extensively engaged other Theories, constituting a continuing discourse from which they may only arbitrarily be excluded. This web of discourse manifests the need for the second criterion of participation in a common debate (Table 10 on page 106). Other

[245] Georges Louis Leclerc Comte de Buffon, "Preuves de la Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi,* 36 vols. (Paris: De l'Imprimerie Royale, 1749), 1: 168-203.

[246] John Ray, *Three Physico-Theological Discourses, Concerning I. The Primitive Chaos, and Creation of the World. II. The General Deluge, its Causes and Effects. III. The Dissolution of the World, and Future Conflagration. Wherein are largely discussed, The Production and Use of Mountains; the Original of Fountains, of Formed Stones, and Sea-Fishes Bones and Shells found in the Earth; the Effects of particular Floods, and Inundations of the Sea; the Eruptions of Vulcano's; the Nature and Causes of Earthquakes. Also an Historical Account of those Two late remarkable Ones in Jamaica and England. With Practical Inferences, 2d ed.* (London: Printed for Sam. Smith, 1693).

[247]

[248] See page 265 for a brief discussion of Pallas' Theory of the Earth.

[249] Whitehurst's Theory is discussed in "Whitehurst's Enigma," beginning on page 668.

[250] Richard Kirwan, *Geological Essays* (London: Printed by T. Bensley, Bolt Court, Fleetstreet, for D. Bremner, Strand, 1799). Kirwan defended a Neptunist view by attempting to refute Hutton's Theory of the Earth.

written contributions toward "the Theory of the Earth" included critical reviews like John Keill's *Examination* of the Theories of Burnet and Whiston,[251] John Murray's *Comparative View*, or D'Aubuisson's "Discours préliminaire."[252] Although Keill disavowed any and all Theories, and Murray declined to articulate a novel Theory, it would be pointless and unproductive indeed to exclude them from the web of controversy that constituted the tradition.[253]

An interesting feature of Theories of the Earth as a textual tradition is that, despite the paradigmatic texts of Burnet, Buffon, Hutton and others, they had no fixed textual base. Unlike a more homogenous commentary tradition, their demarcation was not stable but contingent. It was dynamic in the sense that ongoing engagement with the latest texts perpetually redefined the tradition. The current state of discussion was a moving target, although for rhetorical purposes actors often wrote of previous Theories as fixed or frozen in time. Implicitly recognizing this lack of a fixed textual base, François Ellenberger called attention to the fact that many eighteenth-century naturalists saw their work as imperfect contributions toward "The Theory of the Earth," understood as an ideal, not-yet-realized, future system of understanding. Burnet himself referred not only to his own specific Theory, but to the general discourse, and to the perfected ideal of "The Theory" an angel might write. Similarly, Kenneth Taylor distinguishes between specific and generic senses of Theories of the Earth. In this sense, then, the second textual criterion points to the fact that the ongoing interplay between specific texts and the abstract ideal constitutes the textual tradition of Theories of the Earth.[254]

[251]Keill's *Examination* was introduced above, page 100, with further discussion below, "Keill and the Local Intersection of Contested Textual Traditions," beginning on page 143.

[252]Noted earlier; see page 122.

[253]Cf. the discussion of a comment by Gabriel Gohau on page 334.

[254]François Ellenberger, *La Grande Éclosion et ses Prémices, 1660–1810*, vol. 2 of *Histoire de la Geologie*, 2 vols., Petite Collection d'Histoire des Sciences (Paris: Technique et Documentation—Lavoisier, 1994), 13-16; Kenneth L. Taylor, "Earth and Heaven, 1750–1800: Enlightenment Ideas about the Relevance to Geology of Extraterrestrial Operations and Events," *Earth Sciences History* 17 (1998): 86.

This usage of "The Theory of the Earth," an actor's category, also reflects an ambiguity about the epistemic status of Theories of the Earth. While many Theorists regarded their main conclusions as certain and demonstrated (e.g., Descartes, Burnet, Woodward, Whiston, Hutton, Cuvier), the accumulation of discarded and contrasting Theories made it a matter of critical moment to distinguish between what was sure and what was tentative. Some Theorists advanced their Theories as possible worlds, ideal representations which synthesized current research, heuristically-valuable queries, best guesses given the evidence available, or nondemonstrable but nevertheless probable "likely stories" (e.g., John Ray, Halley, Pallas, Saussure). Their attitude was often that expressed by Thomas Wright:

> How the Author has succeeded in this Point [solving the *Via Lacteal Phaenomenon*], is a question of no great Consequence; he has certainly done his best; another, no Doubt, will do better, and a third perhaps, by some more rational Hypothesis, may perfect this Theory, and reduce the Whole to infallible demonstration: The first System of the solar Planets was far from a true one, but it led the Way to Perfection, and the last we can never too much admire.[255]

Wright wrote not in Theories of the Earth, but in the sister textual tradition of Plurality of Worlds. Like Theories of the Earth, the Plurality of Worlds tradition evolved without a fixed textual base, and was never subsumed under or coextensive with natural philosophy, natural theology, natural history, mineralogy, physical geography, antiquities, etc. Like Theories of the Earth, the Plurality of Worlds tradition was not an established field, discipline, vocation, or literary genre, but a heterogenous and contested textual tradition. For this reason a number of instructive parallels and overlaps between the two textual traditions are noted throughout this essay.

The second textual criterion is not too broad, for it does stipulate meaningful exclusions. This second textual criterion of participation in common debate does not encompass all possible involvement in the Theories of the Earth tradition; rather, it applies only to significant

[255]Thomas Wright, *An Original Theory of the Universe, Founded upon the Laws of Nature, and solving by Mathematical Principles the General Phænomena of the Visible Creation; and Particularly the Via Lactea* (London: Printed for the Author, and sold by H. Chapelle, in Grosvenor-Street, 1750), vi.

public participation. As a textual tradition, Theories of the Earth are best delineated by published works. As we delineate the contours of that textual tradition, however, questions about how the ongoing tradition was continually shaped by nontextual practices and local contexts cry out for investigation, a fact which emphasizes the preliminary character of this essay. In particular, any given historical actor deserves careful study in connection with Theories of the Earth if he or she was a serious reader of texts in the tradition or produced a critical source for any writer in the tradition. Questions of readership, audience, gender, patronage, networking, reception, and social significance are unanswerable without considering additional figures in their local contexts. For example, Isaac Newton engaged in extensive private discussions and correspondence regarding Theories of the Earth which arguably shaped other published texts in the tradition. Should such correspondence be counted as a text in the Theories of the Earth tradition? There is no simple answer to such questions, and it is preferable to reformulate demarcationist questions whenever possible. But clearly, if a serious reader's correspondence was published, circulated to a significant degree, or if it substantially shaped a Theory published by someone else, then that figure has a strong claim to be regarded as a participant in the Theories of the Earth tradition. However, including all "serious readers," "essential sources," or similarly-involved figures would inflate the delineation of Theories of the Earth beyond meaningful limits. Therefore *criteria of relevance* for the Theories of the Earth tradition are not as useful as textual criteria for the more modest purpose of *delineating* the tradition.[256] Yet delineating Theories of the Earth as a textual tradition (the purpose of this essay) facilitates and opens up investigations into local contexts, audiences, or nontextual practices often overlooked by those who try to define "Theory of the Earth" as a conceptual genre or distinct mentality. In the following two sections we will examine two cases which show how Theories of the Earth reflected local situations.

[256] In the *EarthVisions.net* website (footnote 5 on page 9) historical actors who were not authors of published texts constituting the tradition are mentioned on the pages dealing with the Theorists they read, privately discussed, or influenced, rather than receiving their own separate pages.

§ 5-i. Keill and the Local Intersection of Contested Textual Traditions

John Keill (1671–1721) took up his pen in opposition to "world-makers" almost two decades after the first appearance of Thomas Burnet's *Theory of the Earth* (1681). Keill noted that the theory of Thomas Burnet (ca. 1635–1715), "tho it has been published many years, and has been animadverted upon by several, yet it has not been so fully refuted as it might have been, nor has any one shew'd the greatest mistakes in it."[257] The several "animadverters" included Matthew Mackaile and Bishop Herbert Croft of Hereford, both of whom had criticized Burnet in works whose titles included the word "Animadversions."[258] Yet another critic was Erasmus Warren, whose alleged critical oversights in his *Geologia* (1690) provided an occasion for Keill's polemical wit: "Nay, Mr. Erasmus Warren, who has wrote the greatest Volum against it, in my opinion has spoken the least sense about it." Warren, wrote Keill, "begins his discourse with a saying of an old Heathen, that Philosophy is the greatest gift that ever God bestowed on man.… But it is plain to any who will be at the pains to read his Book, that God has thought fit to bestow but very little of that great gift upon him."[259] Yet Warren was one of the first writers to criticize Burnet, and his output (three titles in three years) raised the Burnet controversy to a new intensity. The polemics surrounding Burnet have been treated in some detail by historians, particularly Michael Macklem, Marjorie Nicolson, and David Kubrin.[260] In a checklist of titles involved in the Burnet controversy, Macklem lists 34

[257]John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698), p. 22. Hereafter Keill, *Examination*.

[258]Matthew Mackaile, *Terrae Prodromus Theoricus… by way of Animadversions, upon Mr. Thomas Burnet's Theory, of His Imaginary Earth* (Aberdeen, 1691); Bishop Herbert [Croft], *Some Animadversions Upon… the Theory of the Earth* (London, 1685).

[259]Keill, *Examination*, pp. 22–23. Cf. Erasmus Warren, *Geologia: or, a Discourse Concerning the Earth before the Deluge. Wherein the Form and Properties ascribed to it, in a Book intituled The Theory of the Earth, Are Excepted Against: And it is made appear, That the Dissolution of that Earth was not the Cause of the Universal Flood. Also A New Explication of that Flood is attempted* (London: Printed for R. Chiswell, at the Rose and Crown in St. Paul's Church-Yard, 1690).

books, pamphlets, articles or letters by 21 writers that were published between 1681 and 1700 (Table 13).[261]

TABLE 13. Writers involved in the Burnet controversy listed by Macklem

Authors listed in chronological order; dates given for first editions only.		
1	Thomas Burnet	1681, 1684, 1690, 1690, 1691
2	Isaac Newton (unpublished letter)	1681
3	Herbert [Croft], Bishop of Hereford	1685
4	Erasmus Warren	1690, 1691, 1692
5	Edmund Halley	1691, 1694
6	Matthew Mackaile	1691
7	John Ray	1692
8	John Beaumont	1693, 1694
9	Thomas Robinson	1694, 1696
10	John Woodward	1695
11	L.P.	1695
12	Archibald Lovell	1696
13	William Whiston	1696, 1698, 1700
14	John Arbuthnot	1697
15	John Edwards	1697
16	John Harris	1697, 1698
17	Robert St. Clair	1697
18	John Keill	1698, 1699
19	Thomas Beverley	1698
20	Tancred Robinson	1698
21	Samuel Parker	1700

Although reaction to Burnet's theory was slow to set in, being relatively mild throughout the 1680's, from Macklem's checklist it is clear that the controversy had by no means died down in the 1690's. Keill's *Examination* in fact appeared at the height of the controversy;

260 Michael Macklem, *The Anatomy of the World: Relations between Natural and Moral Law from Donne to Pope* (Minneapolis: University of Minnesota Press, 1958); Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca: Cornell University Press, 1959); David Charles Kubrin, "Providence and the Mechanical Philosophy: The Creation and Dissolution of the World in Newtonian Thought. A Study of the Relations of Science and Religion in Seventeenth Century England" (Ph.D. dissertation, Cornell University, 1968), hereafter Macklem, Nicolson, or Kubrin.

261 Macklem, Appendix I, pp. 97–99. One might add other titles (such as reprints, subsequent editions, related works by Burnet, Robert Hooke, or various reviews in the *Philosophical Transactions*), but Macklem's list provides a convenient and adequate overview of the controversy.

1698 is the peak year, with the greatest number of works as listed by Macklem appearing then, and if Burnet himself is excluded, the three years 1696–98 featured only one less title than the total of the preceding years (Table 14).

TABLE 14. Chronological development of the Burnet controversy

Year	#	Writers
1681	2	Burnet, Newton
1682	0	
1683	0	
1684	1	Burnet; English translation
1685	1	Bishop Herbert
1686	0	
1687	0	
1688	0	
1689	0	
1690	3	Burnet, Warren, Burnet
1691	4	Halley, Warren, Burnet, Mackaile
1692	2	Warren, Ray
1693	1	Beaumont
1694	2	Thomas Robinson, Halley
1695	2	Woodward, L.P.
1696	3	Lovell, Whiston, Thomas Robinson
1697	4	Arbuthnot, Edwards, Harris, St. Clair
1698	5	Keill, Beverley, Whiston, Tancred. Robinson, Harris
1699	1	Keill
1700	2	Parker, Whiston
Total first 15 years, 1681-1695		5 by Burnet, 13 by others
Total last 5 years, 1696-1700		0 by Burnet, 15 by others

Despite Keill's significance in the Burnet controversy, his critique of the "world-makers" has not received a thorough or adequate treatment in accounts of Theories of the Earth generally or of the Burnet controversy in particular.[262] Perhaps this inattention lies in the fact, of course, that every modern geologist or historian knows that the theories of Burnet and Whiston turned out "wrong." Keill has perhaps served as a convenient proxy, surreptitiously to drive that Whiggish point home. If so, this has not been propitious for our understanding of Theories of the Earth as a textual tradition.[263]

Another reason for Keill's relative neglect may reflect the general fate of critics who tear down a work without troubling to construct a better alternative. Should Keill be seen as one of the Earth Theorists, or simply as a detached critic? The latter is an easy and convenient option. After all, no one would think of calling an art critic who never painted a post-impressionist. But in the case of Theories of the Earth the canvas is a text, or a textual tradition. To change the metaphor, Keill is an interlocutor in the play, not outside the play altogether. To downplay Keill's role or to exclude him from participation in the Theory of the Earth tradition would be arbitrary given the web of controversy of which he was an integral part. To do so, furthermore, would obscure from our view several crucial aspects of the tradition and of its transformation in the early eighteenth century. "Minor" actors, even when they are "critics" or "victors," may yet repay our attention. By closely scrutinizing Keill, several aspects of Theories of the Earth in general come into sharper focus.

Keill began his work with a dedication "To the Reverend Dr Mander, the Worthy Master of Balliol College in Oxford." In 1698, when the *Examination* appeared, Keill was an obscure mathematician at Balliol.[264] He had not yet earned the reputation he would later own as one

[262]For example, Collier mentioned Keill in explanatory footnotes to her exposition of Burnet, but devoted little analysis to him. While Rossi singles out Keill for special treatment, claiming that Keill's views were "in many ways exemplary," his account does not provide a close analysis of Keill. To date, the most careful treatments of Keill are to be found in Strong, Kubrin, and Force, but he still awaits a thorough study; E. W. Strong, "Newtonian Explications of Natural Philosophy," *Journal of the History of Ideas* 18 (1957): 49–83; James E. Force, "Some Eminent Newtonians and Providential Geophysics at the Turn of the Seventeenth Century," *Earth Sciences History* 2 (1983): 4–10.

[263]Few historians are satisfied with an explanation of the success of any historical figure's arguments in terms of alleged irrefutability or self-evidence. In their study of experimental culture, Shapin and Schaffer emphasize the element of contingency in the historical development of science: "We want to show that there was nothing self-evident or inevitable about the series of historical judgments in that context which yielded a natural philosophical consensus in favour of the experimental programme." Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), p. 13. Although Keill was a "winner," unlike Hobbes, the historical task is no less difficult. Favorable evaluations of the merits of Keill's arguments should reflect historically-contingent criteria, which may differ from modern perspectives but are essential for our understanding of contemporary estimations of Keill and his significance.

[264]*Biographia Britannica*, v. 4, p. 2801.

of the foremost advocates of Newtonian natural philosophy, reflected in the published form of his Oxford lectures (*Introductio ad veram physicam*, 1701), his election to the Savilian Chair of Astronomy in 1710, or his championing of Newton in the priority dispute with Leibniz over the invention of the calculus.[265] Born in 1671 at Edinburgh, Keill studied mathematics there under David Gregory (1659–1708). He received a Master of Arts at Edinburgh before moving to Oxford with Gregory after the latter's election to the Savilian Chair of Astronomy in 1694.[266]

Keill's timing in 1698 was opportune, for in that year the so-called "Ancients and Moderns" quarrel exploded with a new level of literary output.[267] This quarrel featured as the party of the Ancients the scholars at Christ Church, Oxford, rallying to William Temple with the support of Henry Aldrich, opposed by the Moderns led by William Wotton and Richard Bentley along with their partisans at Cambridge. This is the quarrel that underlay Swift's famous *Battle of the Books*, whose prefatory note to the reader provides a brief (if biased) description of the circumstances of the controversy:

> The following Discourse… seems to have been written about… the year 1697, when the famous dispute was on foot about Ancient and Modern learning. The controversy took its rise from an essay of Sir William Temple's upon that subject, which was answered by W. Wotton, B.D., with an Appendix by Dr. Bentley, endeavouring to destroy the credit of Aesop and Phalaris for authors, whom Sir William Temple had, in the essay before-mentioned, highly commended. In that appendix, the doctor falls hard upon a new edition of Phalaris, put out by the Honourable Charles Boyle (now Earl of Orrery) to which Mr. Boyle replied at large, with great learning and wit; and the doctor voluminously rejoined.…[268]

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265 Keill read lectures on Newtonian natural philosophy at Balliol College, Oxford, "which he explained by proper experiments in his private chamber at the college." *Biographia Britannica*, v. 4, p. 2801; Keill was apparently the first of Newton's expositors to teach Newtonianism by means of such experiments.

266 For information regarding Keill's life, I am relying upon *Biographia Britannica*, v. 4, pp. 2801–2803, which differs in several details from E. W. Strong, who seems to have been followed by James Force.

267 I capitalize Ancient and Modern when referring to seventeenth-century (i.e., modern) advocates of either party, to distinguish references to primary texts written in either ancient or modern eras. A notable survey of this English episode in the Ancients and Moderns quarrel (which does not discuss Keill, but includes excellent accounts of Temple, Wotton, Bentley and other major figures) is Joseph M. Levine, *The Battle of the Books: History and Literature in the Augustan Age* (Ithaca: Cornell University Press, 1991).

In his preface to the *Works* of Richard Bentley, Alexander Dyce enumerated 23 titles involved in this episode of the Ancients and Moderns controversy extending from 1690 to 1705. Again, though this list might be expanded, it will conveniently serve as a rough indication of the course of this episode in the Ancients and Moderns quarrel (Table 15).

TABLE 15. Ancients and Moderns Quarrel

Short titles of works listed by Dyce, with an A or M indicating which party each work supported			
1	Essay Upon Ancient and Modern Learning…, 1690	Sir William Temple	A
2	Phalaridis Agrigentinorum Tyranni Epistolae…, 1695	Charles Boyle	A
3	Reflections upon Ancient and Modern Learning…, 2d ed., William Wotton, with A Dissertation upon the Epistles of Phalaris…, 1697	Richard Bentley	M
4	Fabularum Aesopicarum Delectus, 1698	[Christ Church, ed. Anthony Alsop]	A
5	Dr. Bentley's Dissertations on the Epistles of Phalaris, and the Fables of Aesop…, 1698	Charles Boyle [and other Christ Church wits, especially Atterbury]	A
6	A View of the Dissertation upon the Epistles of Phalaris…, 1698	John Milner	?
7	A Free but Modest Censure on the late Controversial Writings and Debates…, 1698	F. B. of Cambridge	?
8	Examen Poeticum Duplex, 1698	[Christ Church]	A
9	An Essay concerning Critical and Curious Learning…, 1698	Thomas Rymer	M
10	An Answer to a late Pamphlet called an Essay concerning Critical and Curious Learning, 1698	[Christ Church]	A
11	A Vindication of an Essay concerning Critical and Curious Learning…, 1698	Thomas Rymer	M
12	12. A Dissertation upon the Epistles of Phalaris, 1699	Richard Bentley	M
13	The Epistles of Phalaris…, 1699	[trans. S. Whately?]	M
14	A Short Account of Dr. Bentley's Humanity and Justice…, 1699	[Christ Church]	A

[268] Swift more imaginatively continues: "At length, there appearing no end of the quarrel, our author tells us, that the Books in St. James's Library, taking upon themselves as parties principally concerned, took up the controversy, and came to a decisive battle; but the manuscript, by the injury of fortune or weather, being in several places imperfect, we cannot learn to which side the victory fell." Richard Bentley was nominated King's Librarian in 1693, and took up residence at St. James in 1694. Swift served as Temple's assistant, and lived for a time with the Christ Church wits in the 1690s. Charles Boyle, later the Earl of Orrery, should not be confused with Robert Boyle, the Fellow of the Royal Society.

TABLE 15. **Ancients and Moderns Quarrel**

Short titles of works listed by Dyce, with an A or M indicating which party each work supported			
15	An Answer to a late Book written against the Learned and Reverend Dr. Bentley…, 1699	[by author of #13]	M
16	A Letter to the Reverend Dr. Bentley…, 1699		?
17	A Chronological Account of the Life of Pythagoras…, 1699	Dr. Lloyd	M?
18	Dialogues of the Dead…, 1699	Dr. King	A
19	A short Review of the Controversy between Mr. Boyle and Dr. Bentley…, 1701	[Dr. Atterbury]	A
20	Miscellanea, The Third Part, Containing… III. A Defence of the Essay upon Ancient and Modern Learning, 1701	William Temple (published by Jonathan Swift)	A
21	Exercitationes Duae…, 1704	Henrico Dodwello	?
22	A Tale of a Tub… To which is added, An Account of a Battel between the Ancient and Modern Books in St. James's Library, 1704	[Jonathan Swift]	A
23	A Defense of the Reflections upon Ancient and Modern Learning…, 1705	William Wotton	M

According to Dyce's list, eight works involved in the Ancients and Moderns controversy appeared in 1698, more than in any other single year, in contrast to only three in the previous eight years (Table 16). The coincidence of the outbreak of this literary quarrel and Keill's foray into the Burnet controversy is not fortuitous: in the first chapter of his *Examination* Keill took up the offensive against Wotton and Bentley and sided with his fellow Oxonian wits.

TABLE 16. **Chronological development of the Ancients and Moderns quarrel**

Year	#Titles	Ancients[a]	Moderns	Unknown
1690	1	1 (Temple)	0	
1691				
1692				
1693				
1694				
1695	1	1 (Boyle)	0	
1696				
1697	1	0	1 (Wotton and Bentley)	
1698	8	4 ([CC])	2 (Rymer)	(2?)
1699	7	2 ([CC,] King)	4? (Bentley, Whately, Lloyd)	(1?)
1700				
1701	2	2 (Atterbury, Temple)	0	
1702				
1703				
1704	2	1 (Swift)	0	(1?)
1705	1	0	1 (Wotton)	

a. "CC" = Christ Church scholars

Keill began by noting that natural philosophers have a particular propensity for vain fables and unfounded speculations.[269] This propensity belongs to both ancient and modern philosophers who, without sense or reason, cultivate their wild imaginations.[270] The case against the vanity of the ancient natural philosophers might begin with Parmenides, against whom Keill inveighed: "Which of the Poets did ever maintain so ridiculous an opinion, as that it is impossible for Bodies to move?"[271] Keill then recited in turn the absurdities of Anaxagoras, Diogenes, Xenophanes, Anaximander, Anaximenes, and Heraclitus. Not all

[269]"What Plutarch particularly proved of the Stoicks, that they spoke more improbabilities than the Poets, may be extended to a great part of Philosophers, who have maintained opinions more absurd than can be found in any of the most Fabulous Poets, or Romantick Writers." Keill, *Examination*, p. 1 (the first paragraph).

[270]Keill, *Examination*, p. 2.

[271]Keill, *Examination*, p. 2.

ancient philosophers, of course, were without sense and reason, and Keill contrasted the foregoing views to the sound observations underlying the prediction of a solar eclipse by Thales of Miletus.[272] For the presumption of "Epicurus the World-maker" Keill expressed particular disdain: "I am sure a Blind man, who had never seen either Sun or stars, could not have given a worse account of them, than this Philosopher has done; and yet with an unpardonable boldness he pretended to tell us, how the World was made, when it is plain he knew not what it was."[273]

Modern natural philosophers may proudly claim to differ from the ancients, yet Keill sarcastically noted their similar propensity toward pride and pretension:

> Now in this Learned and Inquisitive Age they have at last found out the true and solid Philosophy. They do now perceive the *intimate essence* of all things, and have discovered Nature in all her works, and can tell you the true cause of every effect, from the sole principles of *matter and motion*. If you will believe them, they can inform you exactly, how God made the world; for they do now comprehend the greatest mysteries in nature, and understand the Oeconomy of living Bodies: Nay they understand also very exactly the *Theory* of the Soul, how it thinks, and by what methods it operates on the Body, and the Body on it.[274]

The ancients were not the only philosophers to fall into vain speculation and foolish errors. To "prove that our moderns are as wild, extravagant, and presumptuous as any of the Ancients either Poets, or Philosophers," Keill rehearsed in turn various absurdities of Spinoza, More, Hobbes, Malebranche, and above all, Descartes.[275]

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[272] Of course, the historical accuracy of Keill's rhetoric (both favorable and critical) or the alleged prediction by Thales of an eclipse in 585 B.C. is irrelevant in the present context.

[273] Keill, *Examination*, pp. 4–5.

[274] Keill, *Examination*, p. 6. The significance of this voluntarist tradition with its denial of knowledge of the essences of things (reflected in Newton's General Scholium several years later) is illuminated by Richard Olson's study of the Eucharist and Keill's Anglican High-Church milieu; Richard G. Olson, "Tory–High Church Opposition to Science and Scientism in the Eighteenth Century: The Works of John Arbuthnot, Jonathan Swift and Samuel Johnson," in *The Uses of Science in the Age of Newton*, ed. John G. Burke (Berkeley: University of California Press, 1983), 171–204. On Newton's phenomenalism see footnote 57 on page 34.

[275] Keill, *Examination*, pp. 6ff. For example, describing Malebranche's occasionalism, Keill remarked: "If a Rebellious Son or Subject murther his Father or his Prince by stabbing him, the Man himself does not thrust the Poiniard into his Fathers or Princes Breast, but God Almighty does it.…" Keill, *Examination*, p. 9.

Descartes "was the first world-maker this Century produced," noted Keill, tagging Descartes with the same pejorative he had used for Epicurus.[276] Compared with Aristotle, Descartes was no improvement when it came to vain presumption.[277] The two paradigmatic "world-makers," Epicurus and Descartes, thus served Keill's rhetoric as the two chief exemplars of the presumptuous pride of natural philosophers. The theme of natural philosophers' "unpardonable pride" was epitomized in the very title of "world-maker," so that the Burnet controversy and the Ancients and Moderns quarrel converged in Keill's *Examination*.

Keill wondered that Descartes' "principles of Philosophy" would be believed by anyone, and this provided him the opportunity to ridicule William Wotton, the champion of the Moderns. In his rebuttal to Temple's essay, Wotton had defended Descartes for "Marrying Geometry and Physicks together."[278] While Keill praised Galileo and Kepler for doing just that, he castigated Wotton for believing that Descartes had accomplished anything more than just to boast of it.

> This I think is a clearer demonstration than any in Des Cartes's principles of Philosophy, that Mr. Wotton either understands no Geometry, or else that he never read Des Cartes's principles, for from the beginning to the end of them there is not one demonstration drawn from Geometry; or indeed any demonstration at all. Except Mr. Wotton will say, that every thing that is illustrated by a figure, is a demonstration.… So far was Des Cartes from Marrying Physicks with Geometry, that it was his great fault that he made no use at all of Geometry in Philosophy.[279]

Though Descartes boasted of explaining by matter and motion even the generation of animals he blundered in his very first steps, Keill asserted, for only one of his seven laws of motion held true.[280] After all, Newton had shown the impossibility of Cartesian vortices, demon-

[276]Keill, *Examination*, p. 14.

[277]"But M. Des Cartes the great Master and deliverer of the Philosophers from the tyranny of Aristotle, is to be blamed for all this, for he has encouraged so very much this presumptuous pride in the Philosophers, that they think they understand all the works of Nature, & are able to give a good account of them, whereas neither he, nor any of his followers, have given us a right explanation of any one thing." Keill, *Examination*, pp. 11–12.

[278]Keill, *Examination*, pp. 14–15.

[279]Keill, *Examination*, 14–15.

strating geometrically that planets revolving in a vortex would not follow Kepler's harmonic law. These and other proofs (such as one disproving Descartes' correlation of the tides with lunar apogees and perigees) showed that Descartes' world-making was a "wild chimera of his own imagination."[281]

While the pride of Descartes provided Keill with an occasion to tarnish Wotton by association, the other champion of the Moderns, Bentley, was a Newtonian and therefore a more difficult target. Bentley argued that the Epistles of Phalaris and the Fables of Aesop (hailed as exemplary classical literature by William Temple) were inauthentic—hence, modern, and of no evidential value for the superiority of ancient writers. Thus Bentley's role in the Ancients and Moderns quarrel largely involved not physics but his specialty, classical literature. But in the Boyle lectures of 1692, Bentley enlisted Newtonian natural philosophy in his own version of "world-making" for the service of natural theology, and this provided Keill with a more promising field of attack.[282] That Keill was on a hunting expedition is apparent in his uncharitable misconstrual of Bentley's discussion of the inclination of the Earth's axis. Bentley objected to Burnet's "poetical fancy" (a pejorative cliché made nearly irresistible by the fact that the same view was held by Milton) that the poles of the Earth were originally perpendicular to the plane of the ecliptic and that therefore the primeval world was much warmer than at present. Bentley argued that even if the axis were perpendicular, "we should have had the same measure of heat that we have now."[283] Keill took the "we" in Bentley's comment to mean not the Earth as a whole, but fellow Englishmen inhabiting the temperate zone, and

[280]Keill exposed paradoxes in Descartes laws of motion, for example, "if there be two bodies, one of which is bigger, tho by a very little than the other, the lesser, tho moved with never so great a velocity against the former, which is at rest, can never put it in motion." Keill, *Examination*, p. 13.

[281]Keill, *Examination*, p. 17.

[282]R. J. White writes that after the Boyle lectures, "when Bentley was at war with the scholars of Christ Church over Phalaris, his Boyle lectures were scrutinized by John Keill, his opposite number at Oxford in the propagation of the Newtonian system, in the hope of finding errors for his discomfiture. The vindictive proceeding proved fruitless, save in one particular." R. J. White, *Dr Bentley: A Study in Academic Scarlet* (n.p.: Michigan State University Press, 1968), 72. Rhetorically considered, however, Keill's endeavor was not at all fruitless.

[283]Bentley, *Works*, 2: 187 [note].

refuted this "error" mercilessly. In addition, Bentley had trivially misstated the motion of the Moon relative to the Earth.[284] Armed with his detection of elementary geometrical errors in Bentley's exposition, and predisposed to scorn nonmathematical evidence from texts other than scripture, Keill sarcastically suggested that Bentley should avoid guessing in geometry: "But it were to be wished, that great Criticks would confine their Labours to their Lexicons, and not venture to guess in those parts of Learning which are capable of demonstration...."[285]

To critique Cartesian Theories of the Earth provided Keill with the ideal opportunity to display his mathematical prowess under the banner of Newton, thereby elevating the role of mathematical argument over textual scholarship in questions of natural philosophy. Moreover, by repudiating Burnet's Theory of the Earth in order to attack Wotton (a Cartesian) and Bentley (a Newtonian), Keill aligned himself with the scholars of Christ Church on the side of the Ancients.[286] Despite his criticism of many of the ancient writers, it is no anomaly that Keill should belong to the party of the Ancients. As William Ashworth has pointed out, disputes about Ancients and Moderns throughout the seventeenth century were often less about the superiority of the ancients vs. the moderns, than about with which of the ancients and which of the moderns one agreed (the ancients being no worse, on the whole, than the moderns, with all alike prone to vanity and presumption).[287] This is consistent, as we have

[284]"I know Dr. Bently in his last Lecture for the *Confutation of Atheism*, asserts that tho the axis had been perpendicular, yet take the whole year about we should have had the same measure of heat we have now. But I am not surprised to find an error of this nature asserted by one who as it appears is not very well skilled in Astronomy; for, in the same Lecture, he confidently saies, that *'tis matter of fact and experience that the Moon alwaies shews the same Face to us, not once wheeling about her own Centre*, whereas 'tis evident to any one who thinks, that the Moon shews the same face to us for this very reason, because she does turn once, in the time of her period, about her own Centre." Keill, *Examination*, p. 70. It should be stated that the misstatement only arises from a Newtonian standpoint; Bentley's phraseology was unexceptionable for a classicist; it was a conventional way of speaking dating, of course, from ancient cosmological conceptions where the Moon and planets were conceived as embedded on the inner surface of heavenly spheres.

[285]Keill, *Examination*, p. 70.

[286]"The animadversions in this treatise upon some glaring mistakes of Mr. Wotton, and particularly of Dr. Bentley, must undoubtedly have rivetted him in the favour of Dean Aldrich, the dispute about Phalaris's epistles being then at the height." *Biographia Britannica*, v. 4, p. 2802.

seen, with Keill's contrasts of Thales vs. Epicurus among the ancients, and of Newton vs. Descartes among the moderns.

Apparently Keill's loyalty to the party of the Ancients was noted and appreciated, for soon thereafter Keill was residing in Christ Church at the invitation of Aldrich himself.[288] While Keill credited Dr. Mander of Balliol College with a favorable disposition toward mathematics, it is not too much to say that Newtonian philosophy was encouraged at Oxford (for whatever reason) by Aldrich.[289] In any event, in 1710 Keill was made the Savilian Professor of Astronomy at Oxford, just in time to launch his satirical and polemical skills on behalf of Newton against Leibniz and John Bernoulli.

Keill's position in the Ancients and Moderns quarrel is instructive on several counts. Richard Foster Jones' classic article on the controversy emphasized the significance of natural philosophy as "The Background of the *Battle of the Books*."[290] Keill's participation by itself refutes Jones' characterization of the controversy as "a battle made necessary by the inevitable

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[287]"Investigations into hermeticism, Paracelsian medicine, the reception of Copernicanism, Cambridge Platonism, architectural humanism, and other related areas have revealed that attitudes toward the past were often quite complicated. Sometimes a classical authority was criticized and replaced by another authority, also ancient; the Paracelsians adopted this attitude when they toppled Galen from his place of honor and substituted Hippocrates. Sometimes the authority of classical Greece gave way to an authority of even greater antiquity; we notice this tendency in the hermeticists who sought to reconcile magic and Christianity by resorting to a *prisca theologia*. Often a modern theory was accepted only after it was shown to have classical precedents; many Copernicans viewed their namesake not as a revolutionary, but as the restorer of the ancient doctrines of Aristarchus. Many individual scientists managed to couple an interest in antiquity with the pursuit of science without detriment to either; John Dee and Thomas Browne wrote antiquarian works, Bacon sought truth in classical mythology, Charleton and Aubrey wrote treatises on Stonehenge, Wren embellished the models of classical architecture, and Newton devoted the greater part of his life to an ancient chronology." Ashworth, "Sense of the Past," v-vi.

[288]The *Biographia Britannica* records that in 1700: "Dr Thomas Millington, Sedleian Professor of Natural Philosophy at Oxford, who had been appointed Physician in Ordinary to King William, substituted Mr Keill to read lectures, as his deputy, in the public schools. Our author discharged this office with uncommon reputation; and the term for enjoying the Scotch exhibition at Baliol expiring, he accepted an invitation given him by Dr. Henry Aldrich, Dean of Christ-Church, to reside there." *Biographia Britannica*, v. 4, pp. 2801–2803.

[289]Keill wrote in his Dedication to Dr. Mander: "The Principles on which I have grounded by Arguments in the following discourse being Mathematical, it doth more peculiarly belong to You, whose prudence in so Industriously promoting the Mathematical Sciences, both by your Direction and Encouragement I cannot sufficiently Commend, when I consider what vast improvements have been made, and how many Errors of former Philosophers have been detected by applying Geometry to Natural Philosophy.…" The *Biographia Britannica* affirms that Aldrich encouraged Newtonian natural philosophy, perhaps on the grounds of his favorable acts toward Keill.

[290]Richard Foster Jones, "The Background of the Battle of the Books," *Washington University Studies*, 1920, 7: 99–161.

conflict between Tradition and Progress." Jones argued that the Moderns were the advocates of science and the Royal Society against the Ancients from the old universities who opposed the "new philosophy."[291] Aldrich, for example, Jones describes as an irreconcilable Aristotelian. Jones asks why the scholars at Christ Church were so opposed to Bentley and Wotton, and concludes that they were hostile to a modern, i.e., scientific kind of learning.[292] For these aspects of Jones' argument, of course, Keill and his emphasis upon mathematical argument stands as a decisive counter-instance. As a Christ Church scholar Keill represents the very antithesis of Jones' anti-science, anti-progress, and anti-Newton characterization. Because the Christ Church scholars, including Aldrich, welcomed Keill into their circle, Jones' characterization of them utterly fails.

Jones himself called attention to a revealing allusion to Thomas Burnet at the beginning of Temple's *Essay upon the Ancient and Modern Learning*.[293] For Temple, Burnet symbolized an attitude of over-confidence in modern endeavors, within or without natural philosophy. Temple could not read Burnet (or Fontenelle), he explained, "without some indignation, which no quality among men is so apt to raise in me as sufficiency, the worst composition out of the pride and ignorance of mankind."[294] Temple's talk of "pride and ignorance" resonates with Keill's rhetoric of "vain presumption"—of which it so happened that cosmogony or

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[291]In support, Jones notes that Wotton drew upon articles that had appeared in the Royal Society's *Transactions*, and he soon afterward became a Fellow of the Royal Society. Why Bentley, a classical literary scholar, took up the side of the moderns he explained as follows: "The conflict had nothing to do with pure literature. Wotton was an ardent admirer of classical poetry even in preference to modern. Furthermore, in defending the Royal Society, Wotton met with the sympathy of Bentley, for the latter was associated with the Society in several ways. He was a friend of some of the members, especially Wotton and Newton. By some of the virtuosi he had been chosen to deliver the Boyle sermons, in which he used to good effect the discoveries of Newton. Later we find him establishing a biological laboratory at Cambridge. Furthermore, his own work, I think, shows the influence of the new science. That 'induction of particulars,' by which Wotton says he wrote his Reflections, is prominent in all Bentley's work, while the scientific spirit of his research reflects that of the experimental philosophers. Finally, those who were enemies to the Royal Society were exactly those who were hostile to his own kind of learning. Thus, with his sympathies naturally on the side of the moderns, Bentley's coming to his friend's aid is by no means strange." Jones, "Background," 156–157. Despite the dubious parallel between Bentley's literary products and the Royal Society's Baconian methods, Jones rightly drew attention to the scientific element of the quarrel.

[292]"So the wits of Christ Church were the inheritors of all the old animosity aroused against the new philosophy, and beheld in Wotton and Bentley the guardians of the institution they detested." Jones, "Background," 157.

[293]Jones, "Background," 143.

"world-making," as Keill would have it, provided countless instances, both ancient and modern. Not only did the Ancients and Moderns quarrel prove advantageous for the launching of Keill's career at Oxford, but it shows a revealing glimpse of the extent to which Theories of the Earth engaged broader concerns and overlapped with other textual traditions at the end of the seventeenth century. The rhetoric of vain presumption which Keill employed so effectively against the world-makers was nourished not only by the topsoil of the Ancients and Moderns quarrel, but rooted in the companion textual traditions of Theories of the Earth and the Plurality of Worlds.

Keill's *Examination* has been read as a definitive rebuttal to a predominantly Cartesian genre of speculative world-making, refuting and exposing the great mistakes of most such endeavors as seen in the light of the Newtonian system of the world. Such a view overlooks the fact that Keill was using Newtonian quantitative methods to rebut an enterprise which Newton, up to this time, had supported. Keill's critique did help to establish certain evidential constraints for future Theories of the Earth, so that henceforth in England it was more difficult to ignore quantitative arguments from mathematical physics (such as those regarding the figure of the Earth as an oblate spheroid). Macklem suggests that the "final exchanges" between Keill and Whiston (the latter was also defended by Beverley) "substantially concluded the controversy," bringing the "active phase of the controversy to an end."[295] Kubrin agrees, concluding that "Keill was skillful enough with his pen and his mathematics to achieve his design, generally convincing most people, natural philosophers and laymen alike, that the hypotheses of the world-makers were inadequate to account for their effects.[296] Yet neither the Ancients and Moderns quarrel, nor the debates over the Plurality of Worlds, and still less

[294]Temple, 3: 445; as quoted in Jones, "Background," 143, n. 75. Temple also wrote: "Our learning leads us to presumption, and vain ostentation of the little we have learned, and makes us think we do, or shall, know, not only all natural, but even what we call supernatural things; all in the heavens, as well as upon the earth; more than all mortal men have known before our age; and shall know in time as much as angels." Quoted in Richard Olson, "Tory-High Church Opposition to Science," 184.

[295]Macklem, pp. 35 and 37.

[296]Kubrin, "Providence and the Mechanical Philosophy," p. 330.

Theories of the Earth were discontinued after Keill, diminished by the rise of Newtonianism, or confined to England alone.[297] For example, Whiston's Theories continued to be revised and republished, and Keill's arguments were less effective against Woodwardian Theories based upon natural history and fossil evidence which continued unabated. In Theories of the Earth (like the Plurality of Worlds), episodes of controversy occurred within a textual tradition that was always heterogenous, contested, and of wider scope than any single contest.

Keill's *Examination of Dr. Burnet's Theory of the Earth* must be understood in terms of its immediate context in the late 1690's. Why did Keill write just such a treatise in just such a place at just such a time? Why did Keill go out of his way to lambast Warren, a fellow critic of Burnet?[298] By understanding Keill as a participant in the web of controversy rather than the vanquisher of a mistaken genre the door is opened to grasp that Theories of the Earth were of wide social significance, not ingrown in a narrow Cartesian mold but possessing an open intellectual economy, often converging with other textual traditions such as the Plurality of Worlds and the Ancient and Moderns. The lesson learned from exploring Keill's local context is not the absence of textual traditions, but the need to avoid essentialist definitions of textual traditions. Given the adaptability of Theories of the Earth to local circumstances, it is impossible to sever critiques of Theories of the Earth from the Theories of the Earth tradition.

[297] Kubrin disagrees: "That the cosmogonic tradition has been discontinuous and had to be begun again in a different context from Newton's rather than experiencing an unbroken development since his time need not blind us to the profound role it played in Newtonian metaphysics. Like many of his contemporaries, Newton tried to contend with the dangers implied by immutable scientific laws that the world might be eternal. His somewhat unsuccessful efforts to avoid this implication led him, as it had many others, to make certain assumptions about the nature of the cosmos and its processes, to emphasize its supervision by God, and to try to seek out specific mechanisms by which God might exercise this supervision." Kubrin, "Providence and the Mechanical Philosophy," pp. 336–337. The titles table, or the succession of Woodwardian Theories by writers such as Hutchinson, Bourguet and Scheuchzer suggest that Keill did not achieve a decisive refutation of an homogenous genre.

[298] "I was willing to produce him as an instance, to shew how unfit a man who understands no *Geometry*, is to write a book of *Natural Philosophy*." Keill, *Examination*, p. 26.

§ 5-ii. Hamilton and Literary Genres of Theories of the Earth

As we shall see, William Whiston composed his Theory of the Earth with all the appearance of a Newtonian mathematical physicist and Maillet wrote in dialogue form. Examples such as these suggest that a variety of literary genres could be employed by Theorists of the Earth, and the writing of a systematic treatise in a Cartesian manner was not required. Travel literature or letters from explorers of unfamiliar regions often served as a suitable literary genre. In Chapter 3 we explore the close relation between Pallas' Russian travels and his Theory of the Earth, and the role of Maillet's travel experiences in the Mediterranean as a French diplomat for his Theory. Perhaps the most influential Theory of the Earth published in the form of travel letters was that of Jean André Deluc.[299] In this section, to reiterate the need for the second textual criterion and to illustrate the variety of literary genres which the tradition of Theories of the Earth encompassed we examine a more unlikely example: the correspondence from Italy of the English diplomat William Hamilton (cf. Figure 19).[300]

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[299] Maillet, and the description of Theories of the Earth as a unique *genre of thought*, are discussed in the section "Marginality and Mentalité," beginning on page 335. On Whiston, see "Whiston and Pseudoscience," beginning on page 296, and "A Newtonian Cosmogony: Whiston's Hexameral Theory," beginning on page 584. For examples of Theories in the Cartesian mold, see "Cartesian Cosmogonies," beginning on page 557. On Pallas see page 265ff. Cf. Jean André Deluc, *Lettres Physiques et Morales sur les Montagnes et sur l'Histoire de la Terre et de l'Homme: Addressées à la Reine de la Grande Bretagne* (The Hague: Chez De Tune, 1778); *Lettres Physiques et Morales sur l'Histoire de la Terre et de l'Homme: Addressées à la Reine de la Grande Bretagne,* 5 vols. (Paris: Chez la V. Duchesne, Libraire; The Hague: Chez De Tune, Libraire, 1779); *Lettres physiques et morales sur l'histoire de la terre et de l'homme,* 5 vols. (Paris: V. Duchesne, 1779–1780); *Lettres sur l'Histoire Physique de la Terre, Addressées à M. le Professeur Blumenbach, Renfermant de nouvelles Preuves géologiques et historiques de la Mission divine de Moyse* (Paris: Chez Nyon, 1798); *Geological Travels,* 3 vols. (London: Printed for F.C. and J. Rivington, 1810); *Geological Travels in Some Parts of France, Switzerland, and Germany,* 2 vols. (London: Printed for F. C. and J. Rivington, 1813). The full flowering of geoscience travel literature perhaps occurs with Humboldtian science.

[300] On Hamilton's life and works see the various contributions to Ian Jenkins and Kim Sloan, eds., *Vases and Volcanoes: Sir William Hamilton and His Collection* (Published for the Trustees of the British Museum by British Museum Press, 1996). These studies also include valuable information about the artists and engravers Hamilton employed, both for this correspondence and other publications. Susan Sontag has provided a remarkable exploration of Hamilton's life, with an emphasis on the culture of collecting, in an interesting novel, *The Volcano Lover: A Romance* (New York: Anchor Books, Doubleday, 1992). Hamilton's volcano work is the focus of Mark C. W. Sleep, "Sir William Hamilton (1730–1803): His Work and Influence in Geology," *Annals of Science* 25 (1969). See also Kenneth L. Taylor, "Volcanoes as Accidents: How 'Natural' Were Volcanoes to 18th-Century Naturalists?," in *Volcanoes and History: Proceedings of the 20th INHIGEO Symposium, Napoli–Eolie–Catania, 1995*, ed. Nicoletta Morello, International Commission on the History of the Geological Sciences (Genova: Brigati, 1998), 595–618.

FIGURE 19. Hamilton, 1772, Map of the vicinity of Vesuvius. HSCI.

Explanation. Hamilton sent all but one of the letters considered here from Naples, within sight of Mount Vesuvius. Herculaneum and Pompeii are indicated near Vesuvius. Note also the location above the Gulf of Puzzole of the New Mountain (Monte Nuovo, which arose overnight in 1538).

Hamilton is not regarded as a Theorist of the Earth, yet a close reading of his letters shows that the Theory of the Earth tradition shaped the writing and reception of travel literature. Hamilton drew increasing attention to the significance of his letters precisely as he changed his stance from that of a descriptive naturalist reporting to the Royal Society of London to that of a natural philosopher with sufficient authority to make pronouncements upon "The Theory of the Earth."[301]

TABLE 17. William Hamilton's Letters to the Royal Society of London

#	Date	Location	Pages	Plates/Titles/Notes
1	June 10, 1766	Naples	1–18	
2	December 29, 1767	Naples	19–44	Plates I, II, and III
3	October 4, 1768	Villa Angelica, near Mount Vesuvius	45–53	
4	October 17, 1769	Naples	54–89	"An Account of a Journey to Mount Etna"; Plates IV and V
5	October 16, 1770	Naples	90–173	"Remarks upon the Nature of the Soil of Naples, and its Neighborhood"
6	March 5, 1771	Naples	174–	Revision of an "explanatory catalogue" sent with accompanying specimens to the Royal Society.

Hamilton's letters, accompanied by dramatic engravings of volcanic eruptions (Figure 20), memorably brought that region's geological phenomena before the view of members of the Royal Society of London and readers of that society's *Philosophical Transactions* in the years around 1770. Hamilton's engravings were of the highest quality, as suggested by this description:

> I have also accompanied that collection with a view of a current of lava from Mount Vesuvius; it is painted with transparent colours, and, when lighted up with lamps behind it, gives a much better idea of Vesuvius, than is possible to be given by any other sort of painting.[302]

[301] Sir William Hamilton, *Observations on Mount Vesuvius, Mount Etna, and Other Volcanos: In a Series of Letters, Addressed to the Royal Society… To which are added, Explanatory Notes by the Author, hitherto unpublished* (London: Printed for T. Cadell, in the Strand, 1772). A new edition was published in 1774.

FIGURE 20. Hamilton, 1772, *Plate I,* "View of the Great Eruption of Vesuvius 1767 from Portici." Letter I. HSCI.

Explanation. 1, Vesuvius. 2, Mountain of Somma. 3, Hermitage, separated from Vesuvius by a valley two miles broad. A, crater of Vesuvius. B, mouth of lava eruptions in 1766 and 1767, which flowed as shown in *Plate II*. C, mouth of lava eruption which flowed as shown in *Plate I*. X, Hamilton's location when the lava erupted from C.

Hamilton wrote to inform the Royal Society of an eruption of Vesuvius, adopting the humble rhetoric of an unpretentious reporter who promised to describe appearances rather than attempt to explain causes.[303] As a first-hand witness he would serve in Italy as the faithful eyes and willing pen for the Royal Society. Later, in response to an inquiry from the Secretary of the Royal Society, Hamilton insisted upon the reliability of his communications where,

[302]1767, Hamilton, *Vesuvius*, 41.

[303]Hamilton wrote the first three letters to Lord Morton, the gentleman who submitted them to the Royal Society. The pledge to be faithful to appearances is given on p. 2, but Hamilton immediately offered in an explanatory note that when a storm approaches, the sea of Naples swells, perhaps entering crevices and thereby causing explosions from new fermentations (note -a-, p. 2). Hamilton noted in his second letter that he was able to predict two eruptions on the basis of the quantity of smoke produced (note -g-, p. 23-24). Another invocation of causal, theoretical explanation occurs on p. 30, where Hamilton suggests that rainwater in the bowels of the mountain reacts with lava to produce extraordinary noises. These examples illustrate the remarks made above about the necessity for historical inferences of background theoretical commitments.

among other things, he had described lightning appearing from clouds of ash.[304] However, that the significance of the unusual phenomena which he described should not be lost upon his readers, in his first letter Hamilton suggested that volcanic phenomena such as the "intermision in the fever of the mountain" during the eruption were "well worthy of a curious inquiry, which might give some light into *the theory of the earth*, of which, I believe, we are very ignorant."[305]

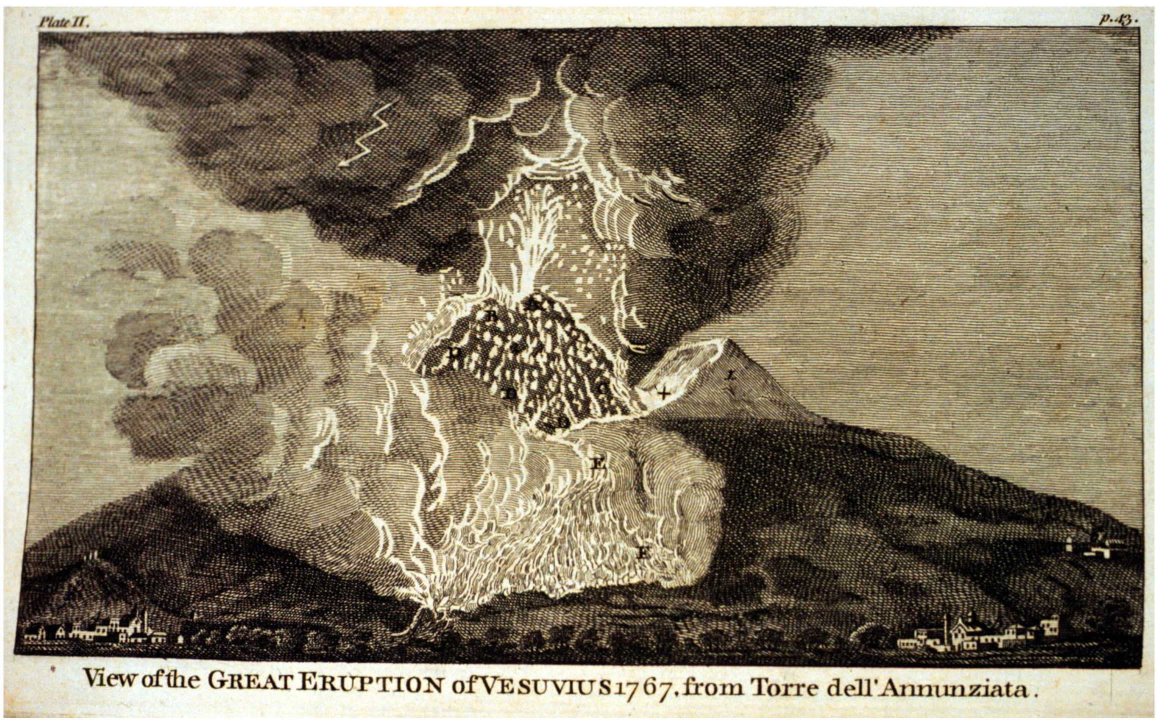

FIGURE 21. Hamilton, 1772, *Plate II,* "View of the Great Eruption of Vesuvius 1767, from Torre dell' Annunziata." Letter I. HSCI.

Explanation. 1, Mountain of Somma. 2, Mount Vesuvius. A, crater of Vesuvius. B, C, X, same as *Plate I*.

[304]"I mentioned nothing but what came immediately under my own observation," further adding that "all the peasants here agree in their account of the terrible thunder and lightning, which lasted almost the whole time of the eruption, upon the mountain only; I think it a circumstance worth attending to." Hamilton, *Vesuvius*, 45; cf. 37-39 (the third letter). For corroboration Hamilton cited the observations of Kircher [*De prodigiosis crucibus*, 1661] as "a very philosophical account" of falling ashes.

[305]Hamilton, *Vesuvius*, note, p. 9; italics added.

From the beginning, the Theory of the Earth tradition shaped both Hamilton's and his readers' understanding of the significance of his reports from a far-away region. The quantity of unfamiliar phenomena before him seemed overwhelming and, once adequately investigated, promised to demonstrate the inadequacy of any Theory of the Earth yet proposed:

> It would require many years close application, to give a proper and truly philosophical account of the Volcanos in the neighbourhood of Naples; but I am sure such a history might be given, supported by demonstration, as would destroy every system hitherto given upon this subject. We have here an opportunity of seeing Volcanos in all their states.[306]

One should not hastily infer that Hamilton rejected the tradition altogether, deigning to participate in the quest for "The Theory of the Earth." Hamilton's belief that previous systems were inadequate did not imply he would be uninterested in a true Theory, given opportunity. When he did so, his would be a Theory emphasizing the power of subterranean fires for the origin of mountains.

Hamilton recounted the famous example of Monte Nuovo (Figure 19). From his observations Hamilton believed it was composed of upheaved strata rather than lava, thereby providing a model for other mountains composed of non-volcanic strata and for that reason not presently considered to be of volcanic origin.[307] For Hamilton, volcanos were not composed simply of volcanic materials, nor restricted to discrete volcanic cones; their mineralogical and topographical effects were quite varied. Generalizing beyond the locality of his observations, Hamilton observed "every sort of matter produced by Mount Vesuvius" during the eruption and thereupon suggested that "many variegated marbles" might be of volcanic origin so that, as a consequence, one might infer that volcanos had existed "in many parts of the world, where at present there are no traces of them visible."[308] To back up his textual reports,

[306]Hamilton, *Vesuvius*, 47.

[307]Hamilton, *Vesuvius*, 50–51.

[308]Hamilton, *Vesuvius*, 40-41. "Marble" may have referred to any stone that could be polished for ornamental purposes.

Hamilton sent specimens of these volcanic products in addition to pictures of landforms and events. Now a tentative thesis could be proposed: "Upon the whole, if I was to establish a system, it would be, that Mountains are produced by Volcanos, and not Volcanos by Mountains."[309]

FIGURE 22. Hamilton, 1772, *Plate IV,* "A View of Mount Aetna from Taormina." Letter IV. HSCI.

In his fourth letter Hamilton provided an account of his ascent of Etna in early autumn of 1769 (Figure 22):

> I was well prepared to visit the most ancient, and perhaps the most considerable, Volcano that exists; and I had the satisfaction of being thoroughly convinced there, of the formation of very considerable mountains by meer explosion, having seen many such on the sides of Etna, as will be related hereafter.[310]

Hamilton explored several cool caverns, often used for storing snow and ice, within the lava flows from an eruption of Etna in 1669. These smaller caverns provided an analogy for great

[309]Hamilton, *Vesuvius*, 52.

caverns which Hamilton inferred lay underneath the volcanos.[311] Several times Hamilton returned to this theme: "…from repeated observations, I dare say, that in all Volcanos, the depth of the craters will be found to correspond nearly to the height of the conical mountains of cinders which usually crown them: in short; I look upon the craters as a sort of suspended funnels, under which are vast caverns and abysses."[312] Hamilton suggested that torrents of water which sometimes disastrously flow from a volcanic crater originate not from communications with the sea, as commonly believed, but from the collection of rainwater within these subterranean cavities.[313]

Vesuvius provided the opportunity to obtain a temporal correlation of volcanic activity with antiquities. Hamilton noticed that on the sides of Vesuvius, strata of "Naples stone" (soft tufa, or pumice, ashes and other burnt matter) alternate with strata of soil. The occurrence of six eruptions since the burial of Herculaneum and Pompeii was inferred from ten feet of material containing six strata of soil alternating with strata of Naples stone.

Hamilton became convinced that not only mountains but the surrounding land was elevated above the sea by the explosive action of subterraneous fires:

> By accompanying these remarks with a map of the country I describe [Plate VI], and with the specimens of different matters that compose the most remarkable spots of it, I do not doubt but that I shall convince you, as I am myself convinced, that the whole circuit (so far as I have examined) within the boundaries marked in the map is <u>wholly and totally the production of subterraneous fires</u>; and that most

[310] Hamilton, *Vesuvius*, 56. "The Piemontese district is covered with towns, villages, monasteries, &c., and is well peopled, notwithstanding the danger of such a situation. Catania, so often destroyed by eruptions of Etna, and totally overthrown by an earthquake towards the end of the last century, has been re-built within these fifty years, and is now a considerable town, with at least thirty-five thousand inhabitants. I do not wonder at the seeming security with which these parts are inhabited, having been so long witness to the same near Mount Vesuvius. The operations of Nature are slow: great eruptions do not frequently happen; each flatters himself it will not happen in his time, or, if it should, that his tutelar saint will turn away the destructive lava from his grounds; and indeed the great fertility in the neighbourhoods of Volcanos tempts people to inhabit them." Hamilton, *Vesuvius*, 58–59.

[311] "Many more [subterraneous caverns] would be found, I dare say, if searched for, particularly near and under the craters from whence great lavas have issued, as the immense quantities of such matter we see above ground, must necessarily suppose very great hollows underneath." Hamilton, *Vesuvius*, 67. This same argument was used by Kircher.

[312] Hamilton, *Vesuvius*, 78.

[313] Hamilton, *Vesuvius*, 83. He excepted water containing shells, which must have originated from the sea.

> probably the sea formerly reached the mountains that lie behind Capua and Caserta, and are a continuation of the Appenines.[314]

Hamilton pointed to observations which he believed explained why lava flows, volcanos, and other signs of fire were not more obvious on the surface of the land:

> …this observation, I believe, will be of more use than any other, in pointing out those parts of the present *terra firma*, that have been formed by explosion. I am convinced, it has often happened that subterraneous fires and exhalations, after having been pent up and confined for some time, and been the cause of earthquakes, have forced their passage, and in venting themselves formed mountains of the matter that confined them… without creating a regular Volcano. The materials of such mountains will have but little appearance of having been produced by fire, to any one unaccustomed to make observations upon the different nature of Volcanos.[315]

Hamilton argued that an eruption adds to the height and bulk of a volcano rather than disrupting it. Lava flows are too great to originate from within the volcano itself. And volcanos are capable of repeated eruptions, which shows that they must be replenished from a deeper source. Thus any new Theory of the Earth should stipulate that the seat of fire must lie not within the volcano, but in deeper subterranean fires that are able to cause new mountains to rise from a plain or the floor of a sea. The origin of Monte Nuovo brought these issues to a focus:

> You have, Sir, from these accounts, an instance of a mountain, of a considerable height and dimensions, formed in a plain, by mere explosion, in the space of forty-eight hours. The earthquakes having been sensibly felt at a great distance from the spot where the opening was made, proves clearly, that the subterraneous fire was at a great depth below the surface of the plain; it is as clear that those earthquakes, and the explosion, proceeded from the same cause, the former having ceased upon the appearance of the latter. Does not this circumstance evidently contradict the system of M. Buffon, and of all the natural historians, who have placed the seat of the fire of Volcanos towards the center, or near the summit of the mountains, which they suppose to furnish the matter emitted?[316]

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[314]Hamilton, *Vesuvius*, 91.

[315]Hamilton, *Vesuvius*, 108–109.

[316]Hamilton, *Vesuvius*, 142–143.

Hamilton chronicled many reports of islands which rose by volcanic eruptions from the sea (Figure 23).[317]

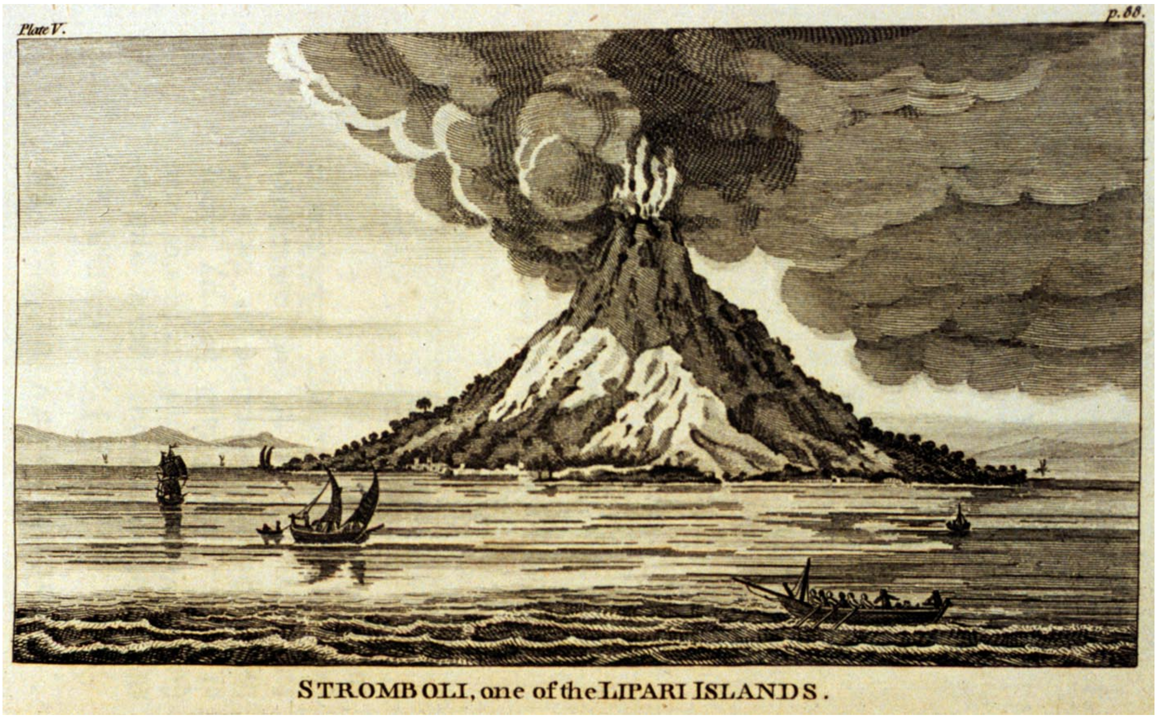

FIGURE 23. Hamilton, 1772, *Plate V,* "Stromboli, one of the Lipari Islands." Letter IV. HSCI.

Hamilton is often quoted by geologist-historians as a precursor of uniformitarianism because he asserted the uniformity of nature and insisted on the slowness with which natural changes occur. These famous remarks, however, were made precisely in the context of his engagement with Theories of the Earth regarding arguments for subterranean fires as the cause of all volcanos:

> ...I dare say, that, after a careful examination, most mountains, that are or have been Volcanos, would be found to owe their existence to subterraneous fire; the direct reverse of what I find the commonly received opinion. ¶ Nature, though varied, is certainly in general uniform in her operations; and I cannot conceive that two such considerable Volcanos as Etna and Vesuvius should have formed otherwise than every other considerable Volcano of the known world. I do not

[317]Hamilton, *Vesuvius*, 157ff.

> wonder that so little progress has been made in the improvement of Natural History, and particularly in that branch of it which regards *the Theory of the Earth*; Nature acts slowly, it is difficult to catch her in the fact [*sic*]. Those who have made this subject their study have, without scruple, undertaken at once to write the natural history of a whole province, or of an entire continent; not reflecting, that the longest life of man scarcely affords him time to give a perfect one of the smallest insect.[318]

In conclusion to this discussion of the second textual criterion, the convergence manifest in this particular study of Hamilton of Theories of the Earth, painstaking observations, and a classic statement of "uniformitarianism" illustrates the need to reassess Theories of the Earth with respect to four major points.

First, Theories of the Earth encompassed regional studies and natural history. Given the great age of the Earth, Hamilton concluded, to catch subterranean fires "in the act" Theorists should take account of a variety of regions, particularly Italy, rather than confining their attention to northern Europe where volcanic activity was absent or more difficult to discern. English Theorists should attend to volcanic regions, where explosive humors of the Earth accumulate in subterranean caverns until liberated through earthquakes and volcanic eruptions.[319] Thus Italy provided a unique window to study the processes by which deep subterranean fires must have acted around the world, wherever there are fertile soils:

> Such wonderful operations of Nature are certainly intended by all-wise Providence for some great purpose. *They are not confined to any one part of the globe*, for there are Volcanos existing in the four quarters of it. We see the great fertility of the soil thrown up by explosion.… <u>May not subterraneous fire be considered as the great plough</u> (if I may be allowed the expression) which Nature makes use of to turn up

[318]Hamilton, *Vesuvius*, 92-93; italics added; the original has a paragraph break after the first sentence quoted. "Fact" was changed to "act" when this passage was reprinted in *Campi Phlegraei* (Naples, 1776), 1: 54. Part of this quotation was discussed earlier; cf. page 113.

[319]At times Hamilton employed macrocosm-microcosm language such as the following: The Earth is "like a body full of humours. When these humours concentre in one part, and form a great tumour out of which they are discharged freely, the body is less agitated; but when, by any accident, the humours are checked, and do not find free passage through their usual channel, the body is agitated, and tumours appear in other parts of that body, but soon after the humours return to their former channel. In a similar manner one may conceive Vesuvius to be the present great channel, through which nature discharges some of the foul humours of the earth: when these humours are checked by any accident or stoppage in this channel for any considerable time, earthquakes will be frequent in its neighbourhood, and explosions may be apprehended even at some distance from it." Hamilton, *Vesuvius*, 108–9.

> the bowels of the earth, and afford us fresh fields to work upon, whilst we are exhausting those we are actually in possession of, by the frequent crops we draw from them?[320]

Subterranean fires, whose existence, depth, and power Hamilton inferred from phenomena in Italy, must have acted on a global scale to produce dry land, mountains, and fertile soil. As with Hutton (who contested Hamilton's view of subterranean fires), teleology provided a clue to natural order; apparently contingent processes, once verified, were applied systematically and universally. Through the course of his letters Hamilton has come far from his original pledge only to describe phenomena without inferring general causes. No longer does he confine his remarks to singular or particular descriptions, or hold back from extending his regional conclusions to a global scale:

> we are apt to judge of the great operations of Nature on too confined a plan. When first I came to Naples, my whole attention, with respect to natural history, was confined to Mount Vesuvius, and the wonderful phænomena attending a burning mountain: but, in proportion as I began to perceive the evident marks of the same operation having been carried on in the different parts above described, and likewise in Sicily in a greater degree, I looked upon Mount Vesuvius only as a spot on which Nature was at present active; and thought myself fortunate in having an opportunity of seeing the manner in which one of her great operations (an operation, I believe, much less out of her common course than is generally imagined) was effected.[321]

The common practice of regarding a regional study as a microcosm of the Earth as a whole is further discussed in Chapter 2.[322]

Second, Theories of the Earth often mobilized evidence in the form of pictures and illustrations as virtual specimens to be read in tandem with textual reports. We have seen that Hamilton supplemented his verbal reports with a broad variety of mobilized artifacts, including not only the maps and illustrations in his correspondence and books, but separately-pre-

[320] Hamilton, *Vesuvius*, 160–161; italics added. Hamilton asserted that this same great plough transports precious gems toward the surface, within reach of miners.

[321] Hamilton, *Vesuvius*, 101–102.

[322] See "Roger's Demarcationist Criteria: Global Directionalism," beginning on page 211.

pared color plates and gifts of physical specimens. Part II of this essay sketches a portrait of Theories of the Earth as a textual tradition based upon a reading of how one type of visual representation (global sections and global views) was integrated with verbal forms of communication in illustrated texts.

Third, to regard Theories of the Earth as a textual tradition removes the prejudice that Theorists were not themselves observers, and (equally important) removes the need to sharply demarcate between Theories of the Earth and other texts. In his first letters Hamilton was tentative, more solicitous of appreciation, more adamantly empirical, and not yet a Theorist of the Earth. However, six years of observation devoted to interpreting phenomena unwitnessed in England, plus the sustained interest of the Royal Society, provided him with sufficient stature to engage in more speculative and theoretical inferences concerning the action of general causes on a global scale. Later still Hamilton collected his letters and republished them, along with annotations and his striking landscape engravings. It would be entirely arbitrary for historians to be preoccupied with arguing that Hamilton was—or was not—a Theorist of the Earth, and if he was, whether he became a Theorist of the Earth at some specific point in the letters published in the *Philosophical Transactions,* or only upon their republication in book form. We have already seen that a Theory of the Earth could be constructed by close empirical analysis of the Earth's smallest parts, such as a single volcano or the region within only about a twenty-mile radius from Naples. And we have noted that a Theory of the Earth could be acknowledged as incomplete, a heuristic for further research, a contribution to the future abstract ideal of "the Theory of the Earth."[323] But historiographically the relevant point is that Hamilton wrote his letters with reference to the Theory of the Earth tradition, citing Theorists such as Kircher and Buffon and situating his descriptions and interpretations

[323]In addition to the previous discussion, see remarks on the heuristic function of Pallas' Theory, page 268. Hamilton specifically indicated that studies in chemistry (vapors and fixed air) and electricity (lightning) would be needed to study Vesuvius further. He concluded with a number of suggestions for further investigation in the style of Newton's queries to the *Opticks*.

as significant because of their importance for the construction of any new Theory of the Earth. Hamilton's work in turn was taken seriously by Erasmus Darwin, John Whitehurst, and Hutton. Thus, like Keill and Murray, he is relevant for the development of the tradition according to the second textual criterion (page 106).

Fourth, Theories of the Earth cannot be regarded as a conceptually-defined endeavor or homogenous literary genre. Unless we employ anachronistic definitions of Theories of the Earth, then in literary genre, rhetorical character, and epistemic styles Theories of the Earth were more heterogeneous than many appreciate. The variety of genres employed by Theorists of the Earth reflects the variety of discourses and the variety of methodological and evidential perspectives which contributed to whole-Earth sensibilities in the seventeenth and eighteenth centuries. Descartes inaugurated the Theory of the Earth tradition with the final part of his major philosophical treatise. Thomas Burnet wrote a history of the Earth which transplanted elements of Cartesian philosophy into a discourse shaped by classical texts, natural history, sacred scripture and apocalyptic prophecy. Athanasius Kircher presented his Theory of the Earth as a visual encyclopedia, in effect a virtual museum or textual counterpart to his natural history museum at the Collegio Romano. Steno's Theory was presented as a disputation in natural philosophy shaped by scholastic forms of argument, John Ray's was a moral exhortation based upon a sermon, Erasmus Warren's was a commentary on the hexameron. Other Theories of the Earth were travel reports, published correspondence, textbooks, popular literature, or encyclopedia articles. Theories of the Earth were a tradition of argument and discourse with many substantive, methodological and metaphysical perspectives, expressed in many literary genres, and were not limited either to systematic treatises or to specifically Cartesian forms. In other words, Theories of the Earth are best described as a contested textual tradition.

§ 6. Textual Criterion 3: External Attribution

Many Theorists situated their own work by reviewing previous Theories of the Earth. These reviews are no more free of the perennial rhetorical temptations of selective citation than were the Theories under review themselves. However, reviewers sometimes noted the extensive but implicit dependence of Theories of the Earth upon works that, prior to that time, were marginalized by silence. Rhetorical suppression renders insufficient the first two criteria of internal self-attribution and extensive (but explicit) participation.[324]

§ 6-i. Louis Bourguet

One brief but noteworthy review by Louis Bourguet (1678–1742) occurs in the three opening paragraphs of his *Mémoire sur la Théorie de la Terre* (1729).[325] As summarized in Table 18, Bourguet sketched the origin of the tradition by classifying the Theories of many of his predecessors into three major types of conceptual schemes: Platonic, Aristotelian, and Mosaic. For each type of Theory Bourguet identified a modern founder, or figurehead. The complete text of this brief passage is as follows:

> 1. La Theorie de la Terre est une Science toute nouvelle, elle consiste à déduire des Phénomenes de la Nature, la formation de nôtre Globe; les changemens qui y sont arrivés depuis, & ceux qui doivent y arriver encore. Les Anciens ont absolument ignoré cette Science.
>
> 2. La premiére Hypothése est celle de la Chute de l'ancien Monde de François Patrice, empruntée de Platon & differemment expliquée par Gonçales de Salas & par Thomas Burnet, qui le prémier a traité la Theorie de la Terre d'une maniére systématique. La seconde Hypothese est celle de Bernard de Palissi sur le séjour naturel de Lacs d'eau salée, ou de la Mer, dans les lieux où l'on trouve des Coquillages, prise d'Aristote & d'autres Anciens; & suivie en tout ou en partie par Alexandre ab Alexandro, Cesalpin, Fracastor, Columna, Scilla, Boccone, & par Mess.

[324] Cf. Table 10, "Textual criteria for participation in Theories of the Earth," on page 106.

[325] Included as text number 14 in Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101.

> Leibniz, Vallisnieri, de Jussieu, de Reaumur, Mayran, & divers autres Savans de ce tems: Ou jointe à la premiére Hypothese en diverses façons par Stenon, & Messieurs Whiston, Halley, Hartsoeker, Buttner, Gautier, & le R. P. Castel.
>
> La troisiéme & derniere Hypothese est celle de la Dissolution du prémier Monde, de Monsieur Jean Woodward, que Messieurs Scheuchzer, Monti, & quantité de Savans d'Angleterre, d'Allemagne & d'Italie ont soutenuë avec beaucoup d'érudition & de force.[326]

Each of these three kinds of Theories are introduced in the pages that follow; at this point, however, the greatest emphasis is given to Platonic Theories for Aristotelian Theories are discussed in Chapter 2 and Mosaic Theories are explored throughout Part II. It should be noted that Bourguet's taxonomy is purely conceptual, not historical. Consequently, references to these three types of Theories in this dissertation are not intended as historical analyses of the primary Platonic, Aristotelian, biblical, and other sources. Bourguet employed these terms as rough conceptual categories, and references to any early modern Theory as "Platonic," "Aristotelian" or "Mosaic" are irrelevant to questions of actual textual influences, or matters of avowed allegiances to Platonism, Aristotelianism or direct reliance upon the commentary tradition for the book of Genesis. Rather, the question at hand is how Bourguet's conceptual taxonomy might have been read by early eighteenth-century readers. To contemporaneous readers, were these three categories plausible? If so, is it possible to reconstruct some of the conceptual associations evoked by each type?[327]

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[326]Louis Bourguet, *Lettres Philosophiques sur la formation des Sels et des Crystaux et sur la Génération & le Mechanisme Organique des plantes et des animaux; a l'occasion de la Pierre Belemnite et de la Pierre Lenticulaire, Avec un Mémoire sur la Théorie de la Terre* (Amsterdam: Chez François L'Honore, 1729), 177-180. Bourguet's citations are noted in the footnotes on the following pages where, when it is possible to definitely identify an edition, full bibliographic references are provided. For convenience, in these references this work is referred to simply as "Bourguet." Table 23 on page 197 compares Bourguet's text (as just presented) with a parallel passage from Élie Bertrand, *Mémoires sur la Structure Intérieure de la Terre* (Zurich: chez Heideggeur et compagnie, 1752), and a later edition of the same work contained in Élie Bertrand, *Recueil de Divers Traités sur l'Histoire Naturelle de la Terre et des Fossiles* (Avignon: Chez Louis Chambeau, Imprimeur-Libraire, 1766). For convenient comparison, in the following references these parallel passages are referred to as "Bertrand (1752)" and "Bertrand (1766)."

[327]In this section I engage in the kind of typological interpretation criticized above on page 51; my defense is that this exercise in reconstructing readers' sensibilities is not offered as a timelessly-valid, enduring taxonomy, and that by invoking more than one essential type it serves an heuristic purpose in probing the limits of a narrow definition of Theories of the Earth as essentially Cartesian.

TABLE 18. **Classification of Theories of the Earth by Louis Bourguet**[a]

1 **Platonic** Crustal Collapse	2 **Aristotelian** Wandering sea	**Combination of 1 and 2**	3 **Mosaic** Dissolution of the World (Deluge)
Francesco Patrizi	**Bernard Palissy**	**Nicolaus Steno**[b]	John Woodward[b]
Gonzales de Salas	**Alexandro Alexandre**	William Whiston	J. J. Scheuchzer[b]
Thomas Burnet	**Andrea Cesal-pino**	**Edmond Halley**	**Giuseppe Monti**[b]
	Girolamo Fra-castoro	**Nikolaas Hart-soeker**	
	Fabio Colonna[b]	**David Sigismund Buttner**[b]	
	Agostino Scilla[b]	**Henri Gautier**	
	Paolo Boccone[b]	**R. P. Castel**	
	G. W. Leibniz[b]		
	Antonio Vallis-nieri		
	Antoine Jussieu		
	R. A. F. de Réaumur		
	J. J. Dortous de Mairan		

a. Louis Bourguet, Lettres Philosophiques… Avec un Mémoire sur la Théorie de la Terre (Amsterdam: Chez François L'Honore, 1729).
Note: Names in bold were not listed in Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101.

b. Persons indicated with a ([b]) were included in a similar list of predecessors by Beringer; Melvin E. Jahn and Daniel J. Woolf, trans. and eds., The Lying Stones of Dr. Johann Bartholomew Adam Beringer, being his Lithographiae Wirceburgensis (Berkeley: University of California Press, 1963). Beringer's list includes three additional names: Athanasius Kircher, Otto von Guericke, and Fabricius Aquapendente.

§ 6-i-a. Platonic Theories of the Earth

Plato offered the first sort of hypothesis, according to Bourguet. Although Bourguet did not elaborate, we may pause to survey some of the major features of Plato's vision of the Earth. In the *Phaedo,* awaiting his imminent death, Socrates discounted his companions' fears that his soul was about to wander alone through the desolate underworld of Hades. Instead, Socrates affirmed that his soul would reside in a wonderful region of the Earth (or perhaps of an ideal Earth), where the inhabitants commune with the gods face to face. His companion Simmias responded: "I myself have heard a great many theories about the earth, but not this belief of yours. I should very much like to hear it." Socrates answered that although he could easily outline his theory of the Earth, to prove that his beliefs were true might not be possible—and, in any event, would require a longer explanation than his few remaining minutes allowed. Thus, to describe his vision of the Earth in a non-demonstrative and even mythical manifesto, Socrates declared that the Earth is spherical, that it lies in the middle of the heavens, and that its size is vast, containing many different, completely unknown regions.[328]

Within the Earth, Socrates continued, there pulses an internal circulation of water and fire, continuous with the land on the surface:

> In the earth itself, all over its surface, there are many hollow regions, some deeper than our region but with a smaller expanse, some both shallower than ours and broader. All these are joined together underground by many connecting channels, some narrower, some wider, through which, from one basin to another, there flows a great volume of water—monstrous unceasing subterranean rivers of waters both hot and cold—and of fire too, great rivers of fire, and many of liquid mud, some clearer, some more turbid, like the rivers in Sicily that flow mud before the lava comes, and the lava stream itself.[329]

The Mediterranean and Caspian Seas are paradigmatic examples of the gulfs or hollow regions mentioned in this passage. Although related to the Atlantis myth as we shall see below, they

[328]Plato, *Phaedo,* 108c-109b; trans. Edith Hamilton and Huntington Cairns, *The Collected Dialogues of Plato, Including the Letters*, Bollingen Series LXXI (Princeton: Princeton University Press, 1961), 90 (hereafter Hamilton and Cairns). Plato's main account of the interior of the Earth, with its various passageways and circulations, is found in the *Phaedo*, 108c–113c. On communing with the gods face to face, cf. *Phaedo,* 111c. That Plato conceived of the Earth as a "round" disc rather than a "spherical" globe is sometimes still debated, as εστιν at 108e4 may be translated either way. However, this passage suggests that the Earth is as round as a twelve-piece leather patchwork ball (110b; quoted on page 375 below); it is worth recalling that in the *Timaeus* (55c), Plato suggested that the ideal world is spherical, but the material world is a dodecahedron (see also footnote 335). For valuable insights on Plato's "geographical" passages, cf. James S. Romm, *The Edges of the Earth in Ancient Thought: Geography, Exploration, and Fiction* (Princeton: Princeton University Press, 1992), 124–128; on page 127 Romm cites the most important discussions in the spherical-vs.-round debate based on this passage in the *Phaedo.* Given the present intention to consider how early modern readers drew upon the Platonic corpus, there is no need to try to disentangle the views of Plato from those Plato attributed to Socrates.

[329]Plato, *Phaedo,* 111d, Hamilton and Cairns, 92.

are appropriated in one of the most interesting ancient descriptions of the lunar surface, where Plutarch wrote "let us not think it an offence to suppose that she [the Moon] is earth and that for this which appears to be her face, just as our earth has certain great gulfs, so that earth yawns with great depths and clefts which contain water or murky air; …"[330] As Socrates suggests that the Earth, if viewed as a globe from space, would display a patchwork of gulfs or hollow regions, so Plutarch argues that just such a view is presented to us on the face of the Moon.[331]

Relying upon the testimony of the poets, Socrates supposed that one subterranean system is formed as the Acheron river flows into a subterranean Acherusian Lake, a meeting place for the souls of the dead. Another system is comprised of the dreadful Cocytus River and its associated lake, the Styx, which holds waters with mysterious powers. The Pyriphlegethon River, a fiery stream from which lava arises, spirals down toward Tartarus, which runs through the center of the Earth:

> All this movement to and fro is caused by an oscillation inside the earth, and this oscillation is brought about by natural means, as follows. One of the cavities in the earth is not only larger than the rest, but pierces right through from one side to the other. It is of this that Homer speaks when he says, 'Far, far away, where lies earth's deepest chasm,' while elsewhere both he and many other poets refer to it as Tartarus.[332]

Plato explained that bottomless waters pulse back and forth through the central Tartarus (Ταρταρον), flowing from one side of the Earth to the other, acquiring various properties

[330]Plutarch, "Concerning the Face which appears in the Orb of the Moon," in *Plutarch's Moralia,* trans. Harold Cherniss, vol. 12, 16 vols., Loeb Classical Library, no. 406 (Cambridge: Harvard University Press; London: Heinemann, 1957), 935c, p. 143. In writing this work, which argues throughout for an Earthlike Moon, Plutarch is widely regarded as indebted to Plato's *Timaeus*. A related passage is found at 944c (p. 209): "just as our earth contains gulfs that are deep and extensive, one here pouring in towards us through the Pillars of Hercules and outside the Caspian and the Red Sea with its gulfs, so those features are the depths and hollows of the moon. The largest of them is called 'Hecatê's Recess,'…." Scott Montgomery cites this passage *in extenso* as "the very first evidence of an effort to name some of the visual features on the lunar surface"; Scott L. Montgomery, *The Moon and the Western Imagination* (Tucson: University of Arizona Press, 1999), 34.

[331]Cf. quote of Socrates on page 400.

from the qualities of the earths through which they pass. The tides therefore move in a continual rhythm much like the breath of a man:

> Into this gulf all the rivers flow together, and from it they flow forth again, and each acquires the nature of that part of the earth through which it flows. The cause of the flowing in and out of all these streams is that the mass of liquid has no bottom or foundation, so it oscillates and surges to and fro, and the air or breath that belongs to it does the same, for it accompanies the liquid both as it rushes to the further side of the earth and as it returns to this. And just as when we breathe we exhale and inhale the breath in a continuous stream, so in this case too the breath, oscillating with the liquid, causes terrible and monstrous winds as it passes in and out.[333]

The analogy between the tides and breathing is only one of many vitalistic resemblances Plato discerned between the human body and the Earth as microcosms, and the living universe as the macrocosm. For Plato not rainfall but the pulsing subterranean movements of water through the Earth provide the source of surface seas, lakes, rivers, springs:

> So when the water retires to the so-called lower region the streams in the earth flow into those parts and irrigate them fully, and when in turn it ebbs from there and rushes back this way, it fills our streams again, and when they are filled they flow through their channels and through the earth; and arriving in those regions to which their ways have been severally prepared, they make seas and lakes and rivers and springs.[334]

The waters drain through complex, winding passageways throughout the Earth:

> Then sinking again beneath the ground, … they empty themselves once more into Tartarus, some much lower, some only a little lower than the point at which they were emitted, but they all flow in at a level deeper than their rise. Some flow

[332]Plato, *Phaedo,* 111e–112a, Hamilton and Cairns, 92. The Acheron, Pyriphlegethon, and Stygian rivers are described in *Phaedo,* 113, as well as in many writers before and after Plato. The subterranean geography of Homer is vague, but see Book XI of the *Odyssey* for suggestive remarks about the activities of shades in the realm of Hades. Hesiod's *Theogony* described a war with the Titans who in the end were confined to a dark region inside the Earth called Tartarus (*Theogony,* 713–814; for an interesting interpretation of Zeus's war with the Titans as based upon the explosive eruption of Santorini [Thera] *circa* 1470 BC see Mott T. Greene, *Natural Knowledge in Preclassical Antiquity* [Baltimore: Johns Hopkins University Press, 1992], chapter 3). Plato also referred to Tartarus as an abode of the wicked in torment after death in the myth of Er in the last book of the *Republic,* 614b-617d (this passage contains a number of images with a long history in Neoplatonic cosmology, including a description of the universe as eight nested spheres, rotating in harmony, suspended by necessity from a chain of light). Virgil mentioned the Styx, Acheron, Lethe, Cocytus, and Pyriphlegethon rivers in Book VI of the *Aeneid*.

[333]Plato, *Phaedo,* 112a–b, Hamilton and Cairns, 92–93.

[334]Plato, *Phaedo,* 112c, Hamilton and Cairns, 93.

in on the opposite side to that on which they came out, and others on the same side, while some make a complete circle and, winding like a snake one or even more times round the earth, descend as far as possible before they again discharge their waters.[335]

TABLE 19. Major Conduits of the Subterranean Circulation, Phaedo 112e

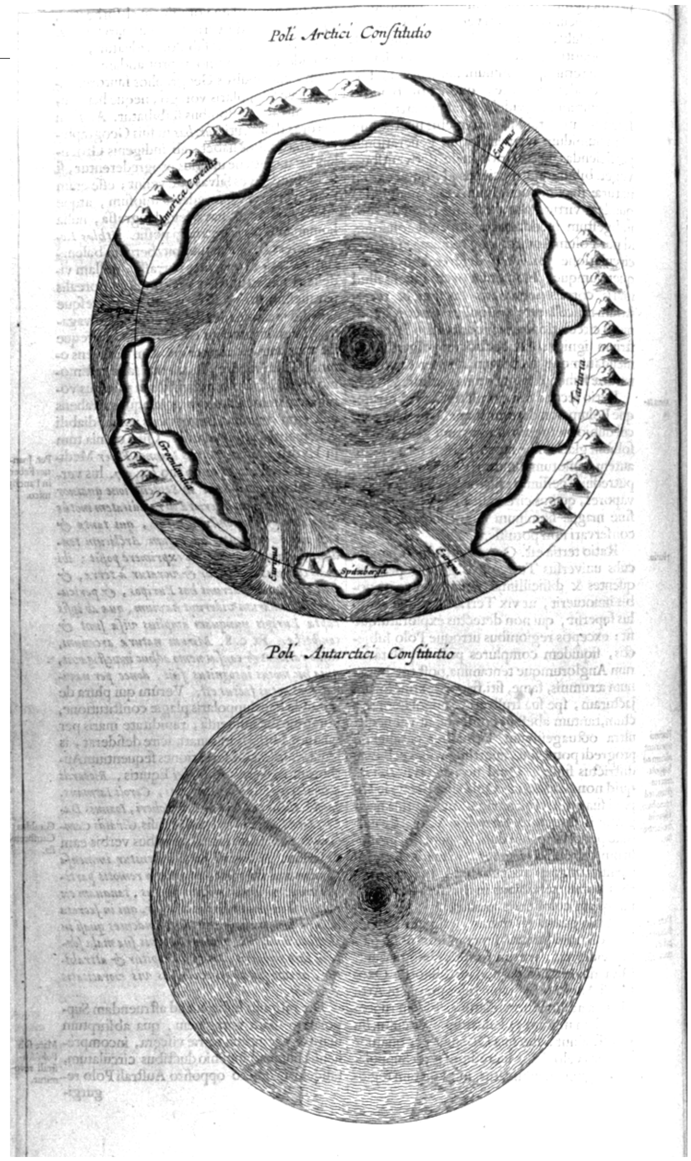
#	River	Description
1	Οκεανοσ; Okeanos	Flows on the surface of the Earth
2	Αξηερον; Acheron	Flows into the Acherusian lake, bearing the souls of the dead
3	Πψριπηλεγετηοντα; Pyriphlegethonta	Flows into Tartarus
4	Στυγιον; Stygion & Κοκυτοσ; Cocytos	Flows into the Styx lake

[335]Plato, *Phaedo,* 112d, Hamilton and Cairns, 93. Plato's next sentence seems to confirm that he conceived of the Earth as roughly spherical: "It is possible to descend in either direction as far as the center, but no further, for either direction from the center is uphill, whichever way the streams are flowing" (Plato, *Phaedo,* 112e, Hamilton and Cairns, 93; cf. *Phaedo,* 108e).

FIGURE 24. Athanasius Kircher, *Mundus Subterraneus* (1665). LH.

Caption. Poli Arctici Constitutio, Poli Antarctici Constitutio, 160. (America Corealis, Greenlandia, Spitzberga, Tartaria.)

Explanation. Polar views showing whirlpools at the entrances to Tartarus.



Although the *Phaedo* is sometimes ignored in many treatments of ancient geological thought, it was well-known to early modern readers, providing a particularly significant idiom for Theories of the Earth. Burnet's appropriation of Tartarus will be examined in Part II, but it would be impossible to tabulate all Theorists who discussed it. Leibniz, a correspondent of Bourguet's, referred favorably to Tartarus in the *Protogaea* (although Bourguet classified his Theory on the whole as Aristotelian). Athanasius Kircher reproduced twin maps of the great polar whirlpools which he thought must serve as entrances to Tartarus (although Bourguet did not mention Kircher in his classification; cf. Figure 24 and Figure 25).[336] However, just as Homer belonged to every Hellene, so a conception of the Earth as laced with internal passageways supporting various elemental circulations, often continuous with the heavens, and often associated with vitalistic microcosm-macrocosm analogies, became a commonplace of poets,[337] natural historians such as Pliny, Stoics such as Seneca,[338] Epicureans such as Lucretius, various hermetists, hexameral commentators, *et al.*, rather than the exclusive possession of Platonism. There were notable dissenters, of course, some of whom will be considered in the following section. Yet despite exceptions, a number of ancient visions echoed Plato's views of the Earth, as Table 20 suggests.

As the passage from Lucretius in Table 20 suggests, the idea of subterranean circulations through underground passageways, however derived, almost inevitably raises the possibility of crustal collapse. Indeed, Bourguet pointed to such events as the essential conceptual characteristic defining Platonic Theories. This concept is found not in the *Phaedo,* but in a famous passage of the *Timaeus*, where Plato envisioned the occurrence of many diverse catastrophes in the Earth's past: "There have been, and will be again, many destructions of mankind arising out of many causes; the greatest have been brought about by the agencies of fire and water, and other lesser ones by innumerable other causes." In particular, Plato recounted the total

[336]For example, Leibniz referred to Tartarus and subterranean cavities in section VI of the *Protogaea*. Kircher's illustrations are from *Mundus Subterraneus, in XII Libros digestus,* 2 vols. bound in 1 (Amsterdam: Apud Joannem Janssonium & Elizeum Weyerstraten, 1665), and *Arca Noë* (Amsterdam: Apud Joannem Janssonium a Waesberge, 1675); on Kircher, see "Kircher's Encyclopedia of the Earth," beginning on page 527. Inexplicably, the *Phaedo* passage is mentioned only as an example of ancient knowledge of erosion in Kathryn Payne, "Greek Geological Concepts to the Age of Alexander" (Ph.D. dissertation, University of Missouri, 1990), 114 and 117.

[337]On Homer, Hesiod, and Virgil see footnote 332 on page 178.

[338]Other Stoics were not all agreed on the cavernous internal structure of the Earth: when the character of Lucilius Balbus undertakes an exposition of Stoic natural philosophy in Cicero's *De natura deorum*, he refers to "a solid (*solida*) and spherical mass gathered into a globe by the natural gravitation of all its parts…" (II.98; p. 219; the Earth's solidity is also affirmed in II.116). However, playing a different theme from Plato, Cicero did emphasize the Stoic notion of circulations between the Earth and heaven: "Her exhalations moreover give nourishment to the air, the ether and all the heavenly bodies" (II.83, p. 203). Again: "But the stars are of a fiery substance, and for this reason they are nourished by the vapours of the earth, the sea and the waters; and when nourished and renewed by these vapours the stars and the whole aether shed them back again, and then once more draw them up from the same source, with the loss of none of their matter, or only of an extremely small part which is consumed by the fire of the stars and the flame of the aether. As a consequence of this … there will ultimately occur a conflagration of the whole world …" (II.118, p. 235). Quotations from Cicero, *De natura deorum, Academica,* trans. H. Rackham, Loeb Classical Library, no. 268 (Cambridge: Harvard University Press; London: Heinemann, 1933).

TABLE 20. Several Ancient Descriptions of Passageways and Circulations within the Earth[a]

Source	Text
Lucretius (circa 50 BC) De rerum natura, 6.535–547 Earthquakes, subterraneous caverns, crustal collapse	"Now attend and learn what is the reason for earthquakes. And in the first place, be sure to consider the earth below as above to be everywhere full of windy caverns, bearing many lakes and many pools in her bosom with rocks and steep cliffs; and we must suppose many a hidden stream beneath the earth's back violently rolls its waves and submerged boulders; for the facts themselves demand that she be everywhere like herself. Since therefore she has these things attached beneath her and ranged beneath, the upper earth trembles under the shock of some great collapse when time undermines those huge caverns beneath; for whole mountains fall, and with the great shock the tremblings in an instant creep abroad from the place far and wide…"[b]
Virgil (70-19 BC) Aeneid, Book VI Subterraneous rivers and passages	"From this place starts the road which leads to Tartarean Acheron. There in mud and mirk seethes the Abyss, enormous and engulfing, choking forth all its sludge into Cocytus.…[c]
Seneca (before 65 AD) Natural Questions Subterraneous caverns, crustal collapse, elemental circulation	(III.16) "There are also laws of nature under the earth, less known to us but no less fixed. Believe me that there exists below whatever you see above. There, too, vast caverns exist, and great recesses, and vacant spaces with mountains overhanging here and there. There are gulfs going into infinity which have frequently swallowed up cities that fell into them and buried the mighty ruins in the depths. These places are filled with air—for no void exists anywhere—and there are marshes enveloped in darkness, and great lakes. Also, living creatures are born there, but they are slow and deformed since they were conceived in dark, heavy air, and in water made torpid by its inactivity."[d]
	(II.5) The Earth is "a material of the universe because the earth includes those universal materials from which is shared out the sustenance for all creatures, all vegetation, all the stars. From this source are provisions supplied for all created things one by one, from this source too provisions for the universe itself, which demands so much. The many stars, which are so active, and so eager day and night, are sustained in their work and in their sustenance by what is provided from this source. All nature takes from the earth as much as is sufficient for its nourishment."[e]

TABLE 20. Several Ancient Descriptions of Passageways and Circulations within the Earth[a]

Source	Text
Pliny the Elder Natural History, Book II, LXVI (completed before 77 AD) Subterraneous passages, elemental circulation	"The reason for this formation must be thought to be the inability of earth when absolutely dry to cohere of itself and without moisture, and of water in its turn to remain still without being held up by earth; the intention of the Artificer of nature must have been to unite earth and water in a mutual embrace, earth opening her bosom and water penetrating her entire frame by means of a network of veins radiating within and without, above and below, the water bursting out even at the tops of mountain ridges, to which it is driven and squeezed out by the weight of the earth, and spurts out like a jet of water from a pipe, and is so far from being in danger of falling down that it leaps upward to all the loftiest elevations. This theory shows clearly why the seas do not increase in bulk with the daily accession of so many rivers. The consequence is that the earth at every point of its globe is encircled and engirdled by sea flowing round it, and this does not need theoretical investigation, but has already been ascertained by experience."[f]
Corpus Hermeticum, (circa 4th century AD) Treatise XVI Subterraneous storehouses, elemental circulation	"Look in the middlemost parts of the earth at the many founts of water and fire gushing forth. In the same place, one observes three natures, those of fire, of water and of earth, depending from one root. Hence, the earth has been believed to be a storehouse of all matter, sending forth supplies of matter and in return receiving substance from above. In this way, the craftsman (I mean the sun) binds heaven to earth, sending essence below and raising matter above, attracting everything toward the sun and around it...."[g]

a. Aristotle's views are reserved for special treatment in the following section.
b. Lucretius, De rerum natura, trans. W. H. D. Rouse, 2d ed., Revised, with new Text, Introduction, Notes, Index by Martin Ferguson Smith, Loeb Classical Library, no. 181 (Cambridge: Harvard University Press; London: Heinemann, 1975), 533.
c. Virgil, The Aeneid, trans. W. F. Jackson Knight (Baltimore: Penguin Books, 1956), 156.
d. Lucius Annaeus Seneca, Naturales Quaestiones, trans. Thomas H. Corcoran, vol. 1, 2 vols., Loeb Classical Library, no. 457 (Cambridge: Harvard University Press; London: Heinemann, 1972), 239. Hereafter, Seneca.
e. Seneca, 107.
f. Pliny the Elder, Natural History, trans. H. Rackham, vol. 1, 10 vols., Loeb Classical Library, no. 330 (Cambridge: Harvard University Press; London: Heinemann, 1938, 1949), 303. The elemental circulation for Pliny was continuous with the heavens, since sunspots are "merely dirt from the earth taken up with the moisture;" for "the stars are undoubtedly nourished by the moisture of the earth" (II.VI, p. 197).
g. Copenhaver, Hermetica, treatise XVI, sections 4-5, p. 59.

destruction of a great civilization, all memory of which had been obliterated when it suddenly sank beneath the waves: "But afterward there occurred violent earthquakes and floods, and in a single day and night of misfortune all your warlike men in a body sank into the earth, and the island of Atlantis in like manner disappeared in the depths of the sea" (Figure 25).[339]

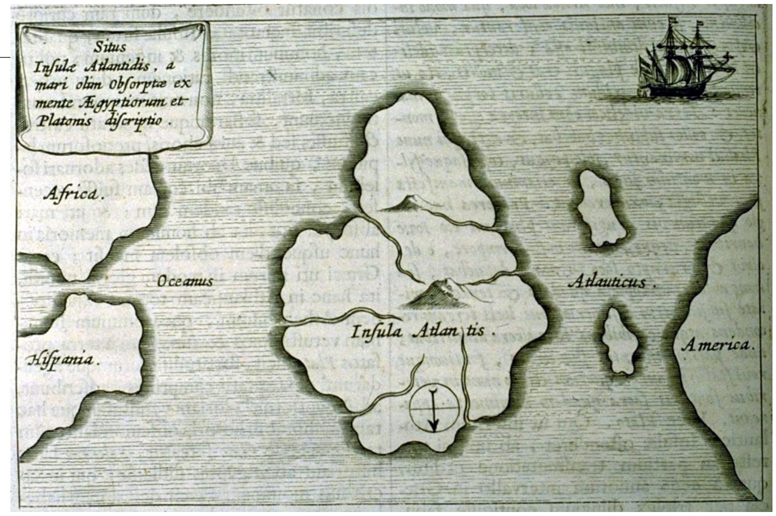


FIGURE 25. Kircher, *Mundus subterraneus*, 82. LH.

Caption. Situs Insulae Atlantidis, a mari olim Obsorptae ex mente Aegyptiorum et Platonis descriptio.

Explanation. Land masses are *Africa* (above left), *Hispania* (below left), *Insula Atlantis* (center), and *America* (right). Oceans are *Oceanus* (left) and *Atlanticus* (right). Kircher's map of the location of Atlantis is upside-down by modern conventions (note compass arrow pointing downward).[340]

Bourguet did not classify the Italian writer Bernardino Ramazzini (1633–1714) in his scheme of Theories, but in the *De fontium* of 1691 Ramazzini examined the artesian wells of Modena and considered their possible origin from subterranean sources of water. Conceding a general system of subterranean communication, Ramazzini cited classical authorities such as Plato, Seneca, Ovid, Virgil and Lucretius, took note of chemical philosophies from Van Helmont to Becher's *Physica subterranea* and spoke often of the "most learned Kircher." Yet from his own observations Ramazzini argued that the area of Modena was so wide that, in order to supply it, a subterranean river would need to be greater than any modern European river.

[339]Hamilton and Cairns, 1157 and 1159-1160; Plato's account of the collapse and destruction of Atlantis is found in the *Timaeus*, 21b–27a. Atlantis also constitutes the entire subject of the unfinished *Critias*. Bourguet and Bertrand (1752) both cited Plato's *Republic* rather than either the *Phaedo* or *Timaeus*. The fascination of the Atlantis myth apparently is perennial: few are the Renaissance scholars who omitted to comment on it, and few are the places never to have been identified with it; for example, in the seventeenth-century Olaus Rudbeck argued that his native Sweden was the lost island (or peninsula) of Atlantis; Gunnar Eriksson, *The Atlantic Vision: Olaus Rudbeck and Baroque Science,* Uppsala Studies in History of Science, ed. Tore Frängsmyr, no. 19 (Canton, MA: Science History Publications; Watson Publishing International, 1994). Modern geological interpretations of Plato's Atlantis myth are reviewed in Dorothy B. Vitaliano, *Legends of the Earth: Their Geologic Origins* (Bloomington: Indiana University Press, 1973), chapter 9. For invaluable commentary on the relation of the Atlantis myth to Plato's thought as a whole see Romm, cited above in footnote 328.

[340]For a discussion of this illustration as related to Kircher's reconstruction of Noah's Deluge, see Edna Kenton, *The Book of Earths* (New York: William Morrow & Company, 1928), 82-83.

Before arguing against the view that the deluge was caused by the collapse of the crust into an underlying abyss of water, Ramazzini recounted the folk-tale of a "wise Abyssinian" who espoused just such a Platonic Theory of subterranean passageways and crustal collapse:

> This wise Abyssinian did say, That in the most ancient Annals of Aethiopia, there is a History of the Destruction of Mankind, and the breaking of the Earth: That in the beginning of the World the Earth was far bigger than now 'tis, and nearer to Heaven, perfectly round, without Mountains and Valleys, yet all Cavernous within like a Spunge, and that Men dwelling in it, and enjoying a most pure Aether, did lead a pleasant Life; and that the Earth brought forth excellent Corn and Fruits without Labour. But when, after a long Flux of Ages, Men were puft up with Pride, and so fell from their first Goodness, the Gods in Anger did shake the Earth, so that a great part of it fell within its own Caverns; and by this means the Water, that before was shut up in dark Holes, was violently squeez'd out, and so Fountains, Lakes, Rivers, and the Sea it self, took its Original: But that Portion of the Earth, which did not fall into these Caverns, but stood higher than the rest, made the Mountains: That the Isles and Rocks in the midst of the Sea, are nothing but Segments of the Earth remaining after the sudden fall of its Mass.[341]

Ramazzini's *De fontium,* with additions, was quickly translated into English by Robert St. Clair. St. Clair's full title reflects his desire to deploy Ramazzini's arguments as an exposé of Thomas Burnet in the midst of controversies over the latter's Theory of the Earth:

> Abyssinian Philosophy Confuted: or, *Telluris Theoria* neither Sacred, nor agreeable to Reason, Being, for the most part, a Translation of Petrus Ramazzini, *Of the Wonderful Springs of Modena.* Illustrated with many Curious Remarks and Experiments by the Author and Translator. To which is added, A New Hypothesis deduced from Scripture, and the Observation of Nature. With an Addition of some Miscellany Experiments.

In Bourguet's review, it was none other than Thomas Burnet who was the first to treat the Theory of the Earth in a systematic manner.[342] Earlier, Bourguet noted, a Platonic Theory had been put forward by J. A. Gonzales de Salas (1588–1651).[343] Ignoring Descartes (whose

[341] Bernardino Ramazzini, *De Fontium Mutinensium admiranda scaturigine Tractatus Physico-Hydro-staticus* (Modena: Typis Haeredum Suliani Impressorum Ducalium, 1691); as translated by Robert St. Clair, *Abyssinian Philosophy Confuted* (London: Printed for the author, and sold by W. Newton, 1697), 88-90. Hereafter, "St. Clair." St. Clair's text is considered below; cf. "St. Clair Confutes the Abyssinian Philosophy, 1697," beginning on page 504.

[342] Bourguet and Bertrand (1752) both cited Burnet, Amsterdam 1699.

account of crustal collapse was a source for Burnet), Bourguet pointed to the great Renaissance Neoplatonist Francesco Patrizi da Cherso (1529–1597) as the founder of Platonic Theories. Indeed, Ramazzini's source (and perhaps through Ramazzini, Bourguet's source as well) for the tale of the "wise Abyssinian" was none other than Patrizi, whom Ramazzini quoted *in extenso* following the passage quoted above.[344]

It is no wonder that Bourguet should have designated Francesco Patrizi as the founder of Platonic Theories of the Earth which, appropriating the Atlantis myth, postulated a crustal collapse of the ancient surface of the world. Patrizi possessed admirable credentials to serve as a figurehead for the Platonic type of Theory. Born almost a century after Marsilio Ficino, the dean of Renaissance Platonists, Patrizi likewise was a Neoplatonist who edited the Hermetic Corpus (but unlike Ficino's edition, Patrizi's edition in the *Nova de universis philosophia* of 1591 included the Treatise quoted in Table 20 which affirmed the circulations of water, air, and fire through subterranean passages[345]). In addition, Patrizi translated works by Philoponos and Proclos, and published Latin editions of the *Chaldean Oracles* and the pseudo-Aristotelian *Theologia*. Beginning circa 1577, Patrizi was the first Professor of Platonic Philosophy at the university of Ferrara. Patrizi's *Nova de universis philosophia,* no less than the

[343]Bourguet and Bertrand (1752, 1766) cited Gonzales De Salas, *De duplici viventium Terra disputatio paradoxica* (Lugduni Batavorum, 1650). I have not yet seen a copy of this work, and do not know whether de Salas either relied upon Patrizi or discussed Plato's *Atlantis*.

[344]After the passage quoted above, Ramazzini inserted an extended quotation from Patrizi, several pages in length (St. Clair, 90-102). Just prior to the passage quoted above, Ramazzini began (St. Clair, 88): "Franciscus Patritius, a Man famous enough for Learning, in a certain Book of his, *Of the Rhetoric of the Ancients,* written in Italian, and Printed at Venice by Franciscus Senensis, Anno 1562. The first Dialogue has a pleasant Story, which he says Julius Strozza had from Count Balthazzar Castillon, and he had from a certain Abyssine Philosopher in Spain." This is the same work cited by Bourguet and Bertrand (1752) as Francesco Patrizi, "Dialoghi della Rhetorica delli Antichi," in *Il Lamberto*, 49ff (Venice: Franciscus Senensis, 1562). Bertrand (1552) also cited a 1552 edition with identical pagination. The *Della retorica*, unavailable to me, consists of ten dialogues.

[345]The first fourteen treatises of the *Corpus Hermeticum* were published by Marsilio Ficino in 1471 and became known collectively as the *Pimander*. The sixteenth through eighteenth treatises were not found in some manuscripts, including that used by Ficino. Although Ficino's edition was reprinted repeatedly through the sixteenth-century and remained the most influential edition through the nineteenth century, the later treatises were included in some sixteenth-century editions, such as Lodovico Lazzarelli's Latin translation published in 1507, the Greek edition of Foix de Candale published in 1574, and the idiosyncratically-organized edition of Francesco Patrizi in his *Nova de universis philosophia* of 1591 (Copenhaver, *Hermetica*, 200, xlviii-xlix). Copenhaver notes that John Everard's 1650 English translation of Patrizi's edition was reprinted as late as the nineteenth century (Copenhaver, *Hermetica*, li).

better-known works of Bacon and Descartes a generation later, was proposed as a systematic replacement of the Aristotelian corpus. Dedicated to Pope Gregory XIV, it boasted the following title:

> A New Philosophy of Universes contained in fifty books, in which one rises to the first cause by the Aristotelian method, not through motion but through light (*lux*) and brightness (*lumen*); then, by a certain new and special method, all of divinity comes into view; finally, the universe is derived from God, its creator, by the Platonic method.… To these books are added the Oracles of Zoroaster…, the treatises and fragments of Hermes Trismegistus … Asclepius … the mystic philosophy of the Egyptians dictated by Plato and taken down by Aristotle.…[346]

The *Nova de universis philosophia* included four parts: *Panaugia* (which develops a light metaphysics); *Panarchia* (which explains the principles of Patrizi's Neoplatonic system); *Pampsychia* (which relates the first two parts to the human soul and the world soul); and *Pancosmia*. In the last part Patrizi defended his own set of four elements: space (*spatium*), light (*lumen*), calor (*heat*), and fluid (*fluor*).[347] Although Clement VIII invited Patrizi to occupy the chair of Platonic Philosophy at the Sapienza in Rome (which he held from circa 1591 to 1597), his *Nova de universis philosophia* was condemned by the Congregation of the Index. No one, however, took Patrizi's condemnation as a reason to de-emphasize crustal collapse and the Atlantis tradition.[348]

TABLE 21. Key Concepts of Platonic Theories

1.	Internal passageways for elemental circulations (water, air, fire)
2.	Vitalistic analogies between the microcosm (human body and Earth) and the macrocosm (universe)

[346]Translation by Brian P. Copenhaver and Charles B. Schmitt, *Renaissance Philosophy*, A History of Western Philosophy, no. 3 (Oxford: Oxford University Press, 1992), 191-192. In general, I have relied upon their discussion of Patrizi for biographical information (pp. 187-195).

[347]As scholars such as John Henry have argued, Patrizi's Neoplatonic concept of light-filled space was significant for seventeenth-century discussions of absolute space by Cambridge Neoplatonists such as Henry More, and Isaac Newton. John Henry, "Francesco Patrizi da Cherso's Concept of Space and its Later Influence," *Annals of Science* 36 (1979): 549–575. Cf. Edward Grant, *Much Ado About Nothing: Theories of Space and Vacuum from the Middle Ages to the Scientific Revolution* (Cambridge: Cambridge University Press, 1981), 199-206.

TABLE 21. Key Concepts of Platonic Theories

3.	Possible rejection of an Aristotelian sublunar/supralunar dichotomy, either because elemental circulations are continuous with the heavens (air, ether), or because of microcosm-macrocosm relations (Neoplatonic, Hermetic, and Stoic)
4.	**Crustal collapse as the mechanism for generating catastrophic earthquakes and floods, with Atlantis serving as the paradigm[a]**

a. Key concept number 4 was Bourguet's essential defining characteristic of Platonic Theories.

§ 6-i-b. Aristotelian Theories of the Earth

The second sort of hypothesis in Bourguet's conceptual taxonomy was Aristotelian. Although we will consider it more extensively in Chapter 2, some brief remarks are necessary here. Aristotle's *Meteorology* is the primary text containing his theory of the Earth, and early modern Theorists drew upon it extensively as the point of departure on many matters. Key passages in the *Meteorology* include further arguments that the interior of the Earth is cavernous; a versatile and extremely long-lived theory of exhalations and vapors; pioneering investigations of the qualities of different kinds of earths; and observations on earthquakes and volcanos. Yet it also contains a refutation of Plato's *Tartarus*, the alleged source of all rivers pulsing to and fro through the center of the Earth.[349] Plato's views on the perpetual oscillation of waters running through the center of the Earth were also rejected by Plutarch (*The Face on the Moon,* 924b), Cicero, and Ovid, among others.[350] Most importantly, Bourguet identified the essential conceptual characteristic of Aristotelian Theories as the supposition of a natural sojourn of the sea wherein the ocean gradually displaces the land and then uncovers it again. This of course would explain why one finds seashells far from the present seas.[351]

The philosophical coherence of Aristotle's theory of the Earth is expressed in his summary of the relations between the land and the sea:

[348]See "Global Views," beginning on page 375.

[349]Aristotle (*Meteorology,* 355b32–356a19).

[350]Plutarch (*The Face on the Moon,* 924b), Cicero (cf. footnote 338).

> It is therefore clear that as time is infinite and the universe eternal that neither Tanaïs nor Nile always flowed but the place whence they flow was once dry: for their action has an end whereas time has none. And the same may be said with truth about other rivers. But if rivers come into being and perish and if the same parts of the earth are not always moist, the sea also must necessarily change correspondingly. And if in places the sea recedes while in others it encroaches, then evidently the same parts of the earth as a whole are not always sea, nor always mainland, but in process of time all change.[352]

Aristotle suggested that

> these changes escape our observation because the whole natural process of the earth's growth takes place by slow degrees and over periods of time which are vast compared to the length of our life, and whole peoples are destroyed and perish before they can record the process from beginning to end.[353]

Aristotle portrayed the Earth as a functional entity in an immutable cosmos, where cyclical motions of terrestrial generation and corruption correspond to the revolutions of the heavenly orbs as the expression of an intelligible natural order.

Despite an abundance of ancient and scholastic commentators,[354] Bourguet attributed the founding of Aristotelian Theories of the Earth to Bernard Palissy (ca. 1510–1590),[355] and a series of anatomists at the Aristotelian center of learning, the University of Padua.

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[351]Ovid described an Aristotelian perspective in oft-quoted lines: "The face of places, and their forms decay; And that is solid earth, that once was sea; Seas, in their turn, retreating from the shore, Make solid land, what ocean was before." Ovid, *Metamorphoses*, XV. The significance of seashells and Aristotle's *Meteorology* for ancient natural knowledge of the Earth is analyzed by Adrian J. Desmond, "The Discovery of Marine Transgression and the Explanation of Fossils in Antiquity," *American Journal of Science* 1975, 275: 692-707. The fundamental ancient observation is still echoed by contemporary popular geology writers, as in this remark from a Pulitzer Prize winning tome nearly 700 pages in length: "If by some fiat I had to restrict all this writing to one sentence, this is the one I would choose: The summit of Mt. Everest is marine limestone." John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), 124. Many ancient and early modern writers might have said the same.

[352]Aristotle, *Meteorology* I.XIV; 353a15–25; trans. Lee, 118–121.

[353]Aristotle, *Meteorology* I.XIV; 351b8–13; trans. Lee, 108–109.

[354]Ancient authors and works cited by both Bourguet and Bertrand (1752) include Aristotle's *Meteorology*, Book I; Strabo's *Geography*, Book I; Plutarch's *de Iside and Osiride*; Eratosthenes, Straton the Physician and Xanthus of Lydia. A few remarks about the medieval and early modern meteorological tradition are offered below in "Case 1: The Meteorological Tradition," beginning on page 222.

[355]Bernard Palissy, *Discovrs admirables, de la natvre des eavx et fonteines, tant natvrelles qv'artificielles, des metaux, des sels & salines, des pierres, des terres, du feu & des emaux* (Paris: M. le Ieune, 1580); cf. Bernard Palissy, *The Admirable Discourses of Bernard Palissy,* trans. and ed. Aurele La Rocque (Urbana: University of Illinois Press, 1957).

These included Alexandre ab Alexandro (1522),[356] Andrea Cesalpino (1519–1603),[357] Girolamo Fracastoro (1483–1553),[358] Fabio Colonna (1567-1650),[359] and other Italian investigators such as Agostino Scilla (1639–1700[360]) and Paolo Boccone (1633–1704[361]). Bourguet reported that in his own time Theories relying upon Aristotelian processes were taken up by Leibniz,[362] Antonio Vallisnieri (1661–1730),[363] and various French savants including Antoine Laurent de Jussieu (1748–1836), René Antoine Ferchault de Réaumur (1683–1757), and Jean Jacques Dortous de Mairan (1678–1771).[364]

The Aristotelian sort of Theory, Bourguet wrote, could be joined to the Platonic by combining gradual marine deposition with crustal collapse (a move which allowed the additional advantage of shortening the necessary timescale). Bourguet's examples were Nicolaus Steno (1638–1686),[365] William Whiston (1667–1752),[366] Edmond Halley (ca. 1656–1743),[367] Nikolaas Hartsoeker (1656–1725),[368] David Sigismund Büttner (1724–1768),[369] Henri

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356Bourguet cited Alexandre ab Alexandro, "*Genial. dierum* Lib. V. Cap. 9" (1522).

357Bourguet cited book I, chapter 2 of Andrea Cesalpino, *De metallicis libri tres* (Romae: Ex typographia A. Zannetti, 1596).

358Fracastoro wrote a number of medical works; Bourguet cited "*Saraina dell' Antichità & Ampieza di Verona*, Lib. 2. Veronae, 1649 and *Museum Francisci Calceolarii* Sect. 3."

359Bourguet cited Colonna's "*de Purpura, & de Glossopetris Dissertatio*."

360Bourguet cited Agostino Scilla, "*La vana speculazioni*… 1670." This was republished after Bourguet as Agostino Scilla, *De corporibus marinis lapidescentibus quae defossa reperiuntur, auctore Augustino Scilla. Addita dissertatione Fabii Columnae de glossopetris* (Romae: Typis A. de Rubeis, 1747).

361Bourguet cited "*Recherches & Observations naturelles*, Amsterdam 1674. *Museo di Fisica e di Esperienze di Paulo o Don Silvio Boccone*, Venezia, 2 vols, 1697." Cf. Paolo Boccone, *Recherches et observations naturelles sur la production du plusieurs pierres, touchant le corail, la pierre etoilée, les pierres de figure* (Paris: Chez Claude Barbin, 1671).

362For Leibniz's combination of a hexameral framework with an Aristotelian view of the formation of the surface of the Earth see footnote 259 on page 556. Bourguet and Bertrand (1752) cited Leibniz, "*Protogaea* in *Actis Erud; Histoire de l'Academie Royale des Sciences* 1706 p. 11ff. and *Miscellanea Societatis Berolinensis*, 1710, Amsterdam, pp 118-120."

363Bourguet and Bertrand (1752) cited Antonio Vallisnieri, *De' Corpi Marini, Che su' Monti si trovano; della loro origine; E dello stato del Mondo avanti'l Diluvio, nel Diluvio, e dopo il Diluvio* (Venice: Per Domenico Lovisa, 1721).

364Bourguet and Bertrand cited articles published severally by Jussieu, Réaumur and Mairan circa 1720.

365Bourguet and Bertrand cited Steno's *Canis Carchariae caput dissectum* (1677) and his *Prodromvs* (1669).

366Bourguet and Bertrand cited Whiston's third London edition (1722).

367Bourguet and Bertrand (1752) referred to "Deux of the *Memoires de M. Halley,* Biblioth. Angl. Tome 12e, seconde part page 337ff." On Halley see "Magnetic Theories of the Earth," beginning on page 631.

Gautier (1660–1737),[370] and Père Louis-Bertrand Castel.[371] The Aristotelian Theories of Bourguet's French and Italian contemporaries have been well-studied by Rappaport; we will return to consider Aristotelian meteorology in Chapter 2.[372]

§ 6-i-c. Mosaic Theories of the Earth

Bourguet's third and last kind of hypothesis, the one he favored, was that of the radical dissolution of the antediluvian world. This hypothesis explains the watery deluge as the unmaking of the world in a return to watery chaos as in the first days of creation. Bourguet claimed that views of the Earth's dissolution were sustained with much force and erudition by John Woodward (1665–1728), an exemplar of this type of Theory. For Woodward, in the course of the deluge the Earth reenacted the first three days of the creation week:

> the Condition of this new Globe, was the same of the old one when first created; it was without Form, that is, not yet reduced to such Form as might render it habitable, and fitted for such Ends as it was made to answer. The Surface of it was plain, even, and spherical; not broken, so as to have any Hills, Valleys, Caverns, or Fissures; all which were absolutely necessary for the Production, and Sustenance of Animals, Vegetables, and Minerals. It was also, like the primitive, void, while all the Waters, that were to be suddenly sent back into the Abyss, which was then void, or empty, and to be remanded again into the Bowels of the Earth, remained yet, without, upon the Surface of it: and till this Sphere of Earth, which was like a Crust, or Shell, was broken, Hills raised, Valleys sunk, and Fissures made, whereby the Waters were to return down again into the Abyss. Afterwards the Waters, withdrawing at the Divine Command, were gathered together unto one Place; viz. into the Abyss, within the Earth, and, which is as a Kind of Appendage to it, the Sea, as before in the original Earth; and the dry Land appeared. And the Earth at

[368]Bourguet and Bertrand cited Hartsoeker's *Principes de Physique*, Paris, 1696; *Conjectures de Physique*, Amsterdam, 1706; *Ecclaircissemens sur les conjectures de Physiques*, 1710; and *Suite des Ecclaircissemens*, 1712.

[369]David Sigismund Büttner, *Rudera Diluvii testes* (Leipzig: J. F. Braunen, 1710).

[370]Henri Gautier, "Nouvelles Conjectures sur le Globe de la Terre," *Bibliotheque des Philosophes* 2 (1721). See translation and commentary by François Ellenberger, "À l'Aube de la Géologie Moderne: Henri Gautier (1660–1737)," *Histoire et Nature: Cahiers de l'Association pour l'histoire des Sciences de la Nature* nos. 7, 9–10 (1975, 1976, 1977).

[371]Bourguet and Bertrand cited Castel's critiquie of Jussieu in the *Mémoires de Trevoux*, Juin 1722.

[372]Rhoda Rappaport, "Fontenelle Interprets the Earth's History," *Revue d'Histoire des Sciences* 44 (1991): 281–300; and Rhoda Rappaport, *When Geologists were Historians*.

> length attained a Form compleat, fitted for Habitation, and to answer the Uses of it.[373]

In addition to Woodward, whose Theory is discussed in Chapter 6, Bourguet cited Johann Jakob Scheuchzer (1672–1733),[374] Giuseppe Monti (1682–1760),[375] and a number of others as exponents of Mosaic Theories.

Ancient authorities for "Mosaic" views of the "dissolution of the world" included Seneca's *Natural Questions*, one of the most-cited meteorological works in the seventeenth and eighteenth centuries, and Basil and Augustine, the seventeenth-century's favorite patristic expositors in the hexameral tradition. In a pattern that we may call "diluvial symmetry," many hexameral commentators quite economically employed a single mechanism for the gathering of the waters on the third day and the deluge of Noah. The symmetry might take the form either of a parallel repetition or of the same mechanism operating in reverse. That is, either the same natural process operating in reverse provided a source of the flood water, or the gathering of the waters was replayed a second time to account for how the flood water drained off the face of the land, or both. Augustine's rarefaction and condensation (Table 22) was one favorite means for achieving creational separation and diluvial dissolution; another was contriving various ways to shift the Earth's center of gravity (discussed in Chapter 2). Or Seneca, Luther, and Woodward each in different ways deployed natural providence or supernatural agency to account for the gathering of the land or the cohesion of water, which of course might be suspended at will or undone at the end of time.

In these Stoic and hexameral traditions the "dissolution of the world" (of the Earth or of the cosmos as a whole) into chaos might be accomplished via any combination of elemental

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[373] John Woodward, *The Natural History of the Earth, Illustrated, Inlarged, and Defended. To which are added, Physical Proofs of the Existence of God, his actual incessant Concurrence to the Support of the Universe, and of all Organical Bodyes, Vegetables, and Animals, particularly Man; with Several Other Papers, On Different Subjects, never before printed*, trans. Benjamin Holloway (London: Printed and sold by Tho. Edlin, 1726), 101-102.

[374] Bourguet (1729) cited Scheuchzer, *Histoire naturelle de la Suisse,* 4 vols. (1706-1716).

[375] Bourguet and Bertrand cited Monti, *de Monumento diluviano nuper in agro Bononiensi detecto* (Bononiae 1719).

transformations: a loss of earthy cohesion, a fiery conflagration, a rarefaction into air or a condensation into a watery deluge. In this way not only were the creation and deluge linked together, but also eschatological conceptions of the end of the world. The following passage from Basil displays some of the Stoic themes underlying expositor's expectations of a future dissolution of the world in a fiery conflagration:

> Now... fire and water are antagonistic to each other, and the one is destructive of the other, fire of water when it prevails over it by its strength, and water of fire when it surpasses it in quantity. It was necessary then, that there should not be strife between them nor that an opportunity should be afforded to the universe for dissolution by the complete cessation of one or the other. The Ruler of the universe ordained from the beginning such a nature for moisture that, although gradually consumed by the power of fire, it would hold out even to the limits prescribed for the existence of the world. He who disposes all things by weight and by measure (for easily numbered by him are even the drops of rain, according to Job [36.27]) knew how long a time He had appointed to the world for its continuance, and how much had to be set aside from the first for consumption by the fire. This is the explanation for the superabundance of water in creation.... Therefore, the creation of heat was necessary for the formation and continuance of things made, and the abundance of moisture is necessary because the consumption by fire is ceaseless and inevitable.[376]

The hexameral tradition appropriated Stoic natural philosophy and in turn provided it in a sanctified form for appropriation by early modern natural philosophers who articulated Mosaic Theories of the dissolution of the world.

[376]St. Basil, *Exegetic Homilies* [*On the Hexaemeron; On Psalms*], trans. Agnes Clare Way, Fathers of the Church, no. 46 (Washington, D. C.: Catholic University of America Press, 1963), 45. Cf. 48–49, where Basil explained that mild temperatures are preserved in a region only by the gradual consumption of the water by the fiery heavens. Indeed, Basil vigorously opposed an Aristotelian position by contending that the ether is hot and fiery. Basil's frequent references to the Ruler of the Universe is one likely source for Newton's reference to the Pantokrater in the General Scholium.

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TABLE 22. Diluvial Symmetry in Augustine

Gathering of the Waters by condensation	Deluge by reverse process of rarefaction
"Now, where were the waters gathered if they had originally covered the whole Earth? When some were pulled back to lay bare the land, to what region were they brought? If there was some bare portion of the Earth where they could be gathered, dry land already was in evidence, and the waters were not occupying the whole. But if they had covered the whole, what place was there in which they might be gathered so that dry land might appear? It surely could not be [contra Basil, Luther, Calvin] that they were raised up, as the grain, after being threshed, is lifted up above the threshing floor to be winnowed and then, when piled in a stack, leaves bare the space that it had covered when it was spread about. Who would make such a statement, seeing that the great tracts of the ocean are spread equally everywhere? Even when mountainous waves are raised up, they are levelled off again with the passing of the storm; and if the tide retreats from certain shores, it must be admitted that there are other coasts where the moving waters come, and that then they make their way again to the land from which they have departed. But if water covered the whole wide world, where would it go in order to leave some of the land exposed? Could it be that water in a rarefied state, like a cloud, had covered the Earth, and that it was brought together and became dense, thus disclosing some of the many regions of the world and making it possible for dry land to appear? On the other hand, it could be that the earth settled in vast areas and thus offered hollow places into which the flowing waters might pour; and dry land then would appear in the places from which the water had withdrawn."[a]	"It was these heavens where our air is that once perished in a flood, as we read in an epistle included in the canon of Sacred Scripture. Now the moist element that had so condensed into water as to rise fifteen cubits above the tops of the highest mountains could not have reached the stars; but, because it had filled all or nearly all the regions of the moist air in which birds fly, the epistle speaks of the perishing of the heavens that had been. This is unintelligible, in my view, unless the heavier air around the Earth was changed into water. Otherwise the heavens did not perish but were raised up higher when water occupied their space. We can more readily believe, therefore, on the authority of this epistle, that those heavens perished and that others (as the sacred writer states) were put in their place by an increase and extension of the watery element, than that the former heavens had been raised up in such a way that the higher heavens yielded place to them."[b]

a. Augustine, *The Literal Meaning of Genesis*, trans. John Hammond Taylor, 2 vols., Ancient Christian Writers, nos. 41–42 (New York: Newman Press, 1982), 1: 33–34.

b. Augustine, *The Literal Meaning of Genesis*, 1: 75. Cf. 2 Peter 3.5-6; Psalm 148.4-5.

§ 6-i-d. Were Theories of the Earth essentially Cartesian?

The rhetorical character of Bourguet's taxonomy is most interesting in its striking omission of the name of Descartes, a paramount case of selective citation and rhetorical suppression which itself illustrates the need for the third textual criterion.[377] Although Descartes is usually regarded today as the originator of the tradition, for Bourguet the pivotal figure who established the discourse was Thomas Burnet. Equally surprising is Bourguet's inclusion of "founding fathers" from a variety of European nations who worked before Burnet, such as Patrizi, Palissy and Cesalpino. Interestingly, Bourguet's insistence upon the modernity of the tradition, in absolute discontinuity with ancient discourse, did not prevent him from classifying modern works according to ancient textual precedents (Plato, Aristotle, and Moses). These fascinating and complex issues alert us to the fact that attempts to demarcate a tradition with precision are notoriously problematic in various ways.[378]

Despite Bourguet's echoing of the distinctive Cartesian claims that "The Theory of the Earth" was a new science, unknown to the ancients, and that it consists of deducing natural phenomena regarding the original formation of the globe and the changes it has undergone or will undergo,[379] no simple characterization of Theories of the Earth as an homogeneously Cartesian tradition will do. While we need not adopt as timelessly valid the confining categories of any conceptual taxonomy, Bourguet's three-fold taxonomy may be quite liberating for those accustomed to thinking of Theories of the Earth as a single, unified conceptual genre. Although Bourguet's taxonomy served as "textbook history" directed to his audience in 1729, not a nuanced historical analysis of seventeenth-century Theories, still Bourguet's classifica-

[377]On the need for the third criterion (of external attribution) due to rhetorical suppression see page 173.

[378]Insightful cautions to keep in mind when reading "founding fathers" accounts are offered by Jan Sapp, *Where the Truth Lies: Franz Moewus and the Origins of Molecular Biology* (Cambridge: Cambridge University Press, 1990), chapter 2, "Founding-father fables," 27-56. See "Controversy and the Rhetoric of Demarcation," beginning on page 307.

[379]For Bourguet's text, see footnote 326 on page 174. Burnet may have been Bourguet's source for the Cartesian claims about the Theory of the Earth which are explored in "Baptizing Descartes," beginning on page 602.

tion cannot be dismissed as a merely idiosyncratic invention; apparently it was plausible enough and still useful enough to be re-presented almost word for word by his Swiss countryman Élie Bertrand nearly 40 years later (Table 23).[380]

Of the three types of Theories, the Platonic mechanism of irreversible crustal collapse appears most clearly directionalist, although either the cyclic Aristotelian Theories or the "Mosaic" Theories could be modified and made compatible with a directionalist perspective. For example, the cyclic elements of the Stoic-hexameral dissolution of the world were often superimposed upon linear conceptions of development, where gradual and incremental changes anticipate the onset of radical discontinuities in the natural order. One might suppose that the hexameral tradition was more prominent in Platonic and Mosaic Theories, and the meteorological tradition more significant for Aristotelian Theories. However, most Theories appropriated aspects of more than one type of Theory, and drew upon additional traditions such as alchemy, mineralogy, antiquities, or geography. Yet the mere existence of lists like Bourguet's illustrates that Theorists of more than one sort explicitly situated their work within a broad and diverse textual tradition.

[380]Élie Bertrand, *Recueil de Divers Traités sur l'Histoire Naturelle de la Terre et des Fossiles* (Avignon: Chez Louis Chambeau, Imprimeur-Libraire, 1766), in the first part ("Phénoménes de la Structure Intérieure de la Terre"), second memoire ("Diverses Hypotheses pour rendre Raison de la Structure Intérieure de la Terre"), 31–34.

TABLE 23. Bourguet and Bertrand

	Bourguet[a]	Bertrand 1752, 1766[b]
Intro	“La Theorie de la Terre est une Science toute nouvelle, elle consiste à déduire des Phénomenes de la Nature, la formation de nôtre Globe; les changemens qui y sont arrivés depuis, & ceux qui doivent y arriver encore. Les Anciens ont absolument ignoré cette Science.” (177)	“Quand il ne s’est agi que d’expliquer comment ces pierres figurées, semblables à des corps marins, d’Animaux & de Végétaux, se trouvoient dans le sein de la terre, les Philosophes se sont partagés en deux classes. Les uns ont dit que ç’avoit toujours été des corps terrestres, dont l’origine devoit être la même que celle des autres Fossiles, qui ont quelque régularité constante. Les <page 32> autres ont regardé tous ces corps comme des restes de la mer, & des dépouilles du régne animal, ou du régne végétal. Pour expliquer ensuite comment la mer avoit pu laisser ces corps dans la terre, on a imaginé une multitude de systêmes différens.[c] (41 [31-32]) Ceux qui ne se sont pas contentés de considérer ces Fossiles; mais qui ont observé qu’ils se trouvent à toutes sortes de profondeurs, dans des Couches uniformément posées, & dans le sein de Montagnes liées entr’elles, ont compris qu’il falloit, en indiquant l’origine de ces corps, rendre raison de la formation même de ces couches, & de la structure général & présente de notre Globe. Dans cette vuë, on a imaginé différentes hypothèses, qui peuvent être rangées sous trois classes. (41–42 [31-32])
[Bertrand Margin:] Chûte du prémier Monde	“La première Hypothése est celle de la Chute de l’ancien Monde de François Patrice, empruntée de Platon & differemment expliquée par Gonçales de Salas & par Thomas Burnet, qui le prémier a traité la Theorie de la Terre d’une maniére systématique.” (177-178)	La première est la Chûte du Prémier Monde, que Thomas Burnet a exposée systématiquement. Cette idée est empruntée de Platon, dans son Dialogue du Régne, d’où Francisco Patrizio l’avoit déja prise. (42 [32]) [1766 only:] Joseph-Antoine Gonzalez de Salas, Auteur Espagnol, profitant de cette idée, la proposa sous une autre forme. ([32])

TABLE 23. **Bourguet and Bertrand**

	Bourguet[a]	Bertrand 1752, 1766[b]
[Bertrand Margin:]: Séjour de la Mer sur la terre	"La seconde Hypothese est celle de Bernard de Palissi sur le séjour naturel de Lacs d'eau salée, ou de la Mer, dans les lieux où l'on trouve des Coquillages, prise d'Aristote & d'autres Anciens; & suivie en tout ou en partie par Alexandre ab Alexandro, Cesalpin, Fracastor, Columna, Scilla, Boccone, & par Mess. Leibniz, Vallisnieri, de Jussieu, de Reaumur, Mayran, & divers autres Savans de ce tems: Ou jointe à la premiére Hypothese en diverses façons par Stenon, & Messieurs Whiston, Halley, Hartsoeker, Buttner, Gautier, & le R. P. Castel." (178-179)	La seconde est le Séjour successif de la mer sur les terres, d'où elle s'est retirée peu à peu. Cette idée a été diversement présentée de nos jours par Mrs. De Leibnitz, Vallisnieri, de Jussieu, de Reaumur, de Mayran, Linnaeus, Celsius & tout récemment par Mrs. De Maillet & De Buffon, Aristote & quelques Anciens avoient déja été, à près, de cette opinion. (42-43 [32-33]) Ce changement du Lict [Lit, 1766] de la Mer a été diversement combiné avec la chûte d'une partie du prémier monde, & d'autres suppositions par Stenon, Whiston, Halley, Hartsoeker, Buttner, Gautier, le P. Castel, [1766 adds: M. B. de Jussieu] & quelques autres Sçavans. (43 [33])[d]
[Bertrand Margin:] Dissolution de l'ancien Monde	"La troisiéme & derniere Hypothese est celle de la Dissolution du prémier Monde, de Monsieur Jean Woodward, que Messieurs Scheuchzer, Monti, & quantité de Savans d'Angleterre, d'Allemagne & d'Italie ont soutenuë avec beaucoup d'érudition & de force." (179-180)	La troisième Hypothèse générale est celle de la Dissolution du Prémier Monde par le Déluge. Jean Woodward en est l'Inventeur. Elle a été suivie par Jean Jacques Scheuchzer, le Pline de la Suisse, par Monti, par Bourguet, & par divers autres Sçavans. Quelques uns y ont aporté des changemens, croïans, par là, pouvoir mieux la défendre. C'est ce qu'on voit, en particulier, dans le Traité des Pétrifications imprimé à Paris en 1742. (44)

a. Louis Bourguet, Lettres Philosophiques sur la formation des Sels et des Crystaux et sur la Génération & le Mechanisme Organique des plantes et des animaux; a l'occasion de la Pierre Belemnite et de la Pierre Lenticulaire. Avec un Mémoire sur la Théorie de la Terre (Amsterdam: Chez François L'Honore, 1729).

b. Élie Bertrand, Mémoires sur la Structure Intérieure de la Terre (Zurich: chez Heidegguer et compagnie, 1752). 1st part: Phénoménes de la Structure Intérieure de la Terre, 3. Second memoire of first part: "Diverses Hypotheses pour rendre Raison de la Structure Intérieure de la Terre"; [pages in square brackets from 1752 ed; typography follows 1752], pp. 31-34 [41-44]. Citations in previous footnotes are given in full if the edition was clearly indicated.

c. 1766 edition note: A.L. Moro; de Crostacei, ch. III, Book I, p. 10ff.

d. No citations for the Aristotelian section in Bourguet 1729 were omitted in Bertrand 1752. Bertrand 1752 added volume 1 of Buffon's Histoire Naturelle.

§ 6-ii. Hutton and Cuvier

Of course, such lists easily could be lengthened. Nor should it be supposed that lists of works in the tradition were limited to earlier texts like Bourguet's—indeed, to obtain a short list suggesting an additional variety of titles and dates in the tradition, Table 24 collates the much later attributions of Cuvier and Hutton. We will not pause here to examine specific works in this table, although references to many of them are made in the following chapters. However, one of the first general impressions of the table is that neither list was by any means intended to be complete: in a slightly earlier work Cuvier stated that at least eighty systems of geology had been proposed in his day, and Hutton provided an adjacent, similar critique of Neptunist mineralogists. The choice of predecessors is interesting: only Cuvier included Kepler as an early-modern forerunner of animistic Theories of the Earth. Only Hutton included Deluc, although Cuvier himself was significantly influenced by Deluc's work. But neither are these lists idiosyncratic; Cuvier's list was widely emulated—for example, by the English geologist William Phillips—and Hutton's was echoed in later English debates between Huttonians and Neptunists.

TABLE 24. Theories of the Earth attributed by Cuvier or Hutton

<table>
<tr><th>Theorist</th><th>Title[a]</th><th>Date</th><th>Cuvier</th><th>Hutton</th></tr>
<tr><td>Johann Kepler</td><td>Scattered passages in many works, including Harmonices mundi</td><td>1619</td><td>•</td><td></td></tr>
<tr><td>René Descartes</td><td>Principia Philosophiae</td><td>1644</td><td>•</td><td></td></tr>
<tr><td>Thomas Burnet</td><td>Telluris Theoria Sacra, 1681; Theory of the Earth, 1684</td><td>1681</td><td>•</td><td>•</td></tr>
<tr><td>Gottfried Wilhelm Leibniz</td><td>Protogaea (1693, 1749)</td><td>1693</td><td>•</td><td></td></tr>
<tr><td>John Woodward</td><td>Essay toward a Natural History of the Earth</td><td>1695</td><td>•</td><td></td></tr>
<tr><td>William Whiston</td><td>New Theory of the Earth</td><td>1696</td><td>•</td><td></td></tr>
<tr><td>Johann Jakob Scheuchzer</td><td>Herbarium diluvianum (1723), Physica sacra (1731), etc.</td><td>1723</td><td>•</td><td></td></tr>
<tr><td>Benoît de Maillet</td><td>Telliamed</td><td>1729</td><td>•</td><td>•</td></tr>
<tr><td>Buffon</td><td>Histoire & Théorie de la Terre, Preuves de la Théorie de la Terre, in l'Histoire naturelle</td><td>1749</td><td>•</td><td>•</td></tr>
<tr><td>Buffon</td><td>Époques de la Nature</td><td>1778</td><td rowspan="2"></td><td rowspan="2">•</td></tr>
<tr><td>Jean André Deluc</td><td>Various collections of letters, including Lettres Physiques et Morales sur l'Histoire de la Terre et de l'Homme</td><td>1779</td></tr>
<tr><td>James Hutton</td><td>"System of the Earth," "Theory of the Earth" (1788), Theory of the Earth (1795)</td><td>1785</td><td>•</td><td>•</td></tr>
</table>

TABLE 24. Theories of the Earth attributed by Cuvier or Hutton

Theorist	Title[a]	Date	Cuvier	Hutton
Jean Claude Delamétherie	Théorie de la Terre	1795	•	
Louis Bertrand	**Renouvellemens Périodiques des Continens Terrestres**	1799	•	
Jean Baptiste de Lamarck	**Hydrogéologie**	1802	•	
John Playfair	Illustrations of the Huttonian Theory of the Earth	1802	•	
M. de Marschall	**Researches respecting the Origin and Developement of the present State of the Earth?**	1802	•	
Patrin	"Esquisse d'une théorie de la Terre"	1803	•	
Georges Cuvier[b]	" **Discours préliminaire**"	1812	•	
Déodat de Dolomieu	**Journal de Physique?**	1784?	•	
Jean-Honoré-Robert de Paul, chevalier de Lamanon	**Journal de Physique**	1781, 1782, 1784	•	

a. Titles in bold were not included in either Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101, or Table 18, "Classification of Theories of the Earth by Louis Bourguet," on page 175.
b. Cuvier and Hutton themselves represent cases of internal attribution; for documentation, see below, page 276 (Hutton), and beginning on page 314 (Cuvier).

§ 7. Are Textual Criteria Adequate?

Although the delineation of any contested textual tradition remains somewhat fuzzy, with soft edges, the three textual criteria listed in Table 10 on page 106 demonstrate the participation of a given writer in the Theory of the Earth tradition. Were we to insist upon a discrete, hard-edged definition, one might regard works that satisfy all three historical criteria as *first-order* texts in the tradition, works meeting any two of the criteria *second-order* texts, and works meeting any one criterion *third-order* texts. The founders cited by Bourguet, and works providing sustained critical assessments of acknowledged Theories, are thus at least third-order texts and therefore of significance for the tradition. But the apparent objectivity gained by such a quantitative manner of proceeding is obviously artificial.[381]

"Theory of the Earth" may be just a name. However, a nominal existence is still a reality, at least for the historian. Why did the name endure? The fact that so many different works appropriated that name imparts to Theories of the Earth a temporal, diachronical dimension, which neither commits the historian to reification of the tradition nor presupposes any essential defining characteristics. This temporal dimension is pre-eminently textual and rhetorical in character. Too often, the tendency has been to restrict one's focus only to a single work or writer, which fails to address widespread mischaracterizations of the tradition as a whole—a discourse which shaped many aspects of readers' expectations and of the writers' self-acknowledged context. When a given author or reader situated a work within an extensive textual tradition, to discount that temporal extension in our interpretation of the individual work inevitably leads to distortions as we fail to appreciate how it was read or meant to be read.

Guided by the three criteria, a rough delineation of the tradition should provide an adequate basis for promoting more illuminating contextualized local studies. Without such criteria, the very attempt to define the tradition with precision requires the historian to debate the historical actors themselves, absolutizing a reified moment of the tradition as the reference point for historiographical discussion. Such a course results in ludicrous spectacles because the actors' definitions of a Theory of the Earth were contradictory. For example, on what possible grounds should a historian side with Hutton's definition of the tradition against Buffon's, or vice-versa?[382] Yet too frequently this is what happens when Theories of the Earth are viewed from the standpoint of a single local context rather than understood as an extended textual tradition transcending local boundaries as a mobile boundary object, a repository of conceptual, rhetorical, idiomatic and discursive resources. What a proper Theory of the Earth

[381]This method would leave Descartes' work as only a second- or third-order text, for example, since an originating text in a professedly novel tradition would encounter obvious difficulties in identifying itself as a member of an ongoing, established tradition. That it is surely better to set aside the demarcationist agenda altogether is further suggested by the fact that works near the end of the tradition, such as Hutton's and Cuvier's, would raise analogous definitional paradoxes (on Cuvier see "Controversy and the Rhetoric of Demarcation," beginning on page 307).

[382]This argument is extended in Chapter 3 where the definitions of Theorists such as Hutton, Buffon and Cuvier are examined at length.

should be, that is, what the tradition was about, was one of the central points of contention in the ongoing constitution of the tradition. What may a historian do when the actors disagree on the constitution of the tradition, if one desires to avoid taking sides? To reassess this textual tradition, the three criteria offer an alternative means of delineating the tradition.

The three textual criteria do not constrain historical analysis by employing *a priori* conceptual criteria or extraneous philosophical categories that would arbitrarily stipulate more restrictive definitions. Whether a given work was a Theory of the Earth was often contested by historical actors, and similarly, often remains a contested issue among modern interpreters. With a textual approach, however, the arbitrariness of selection ceases to be an insuperable problem. This is so because recognizing the historical character of Theories of the Earth as a contested textual tradition shifts the emphasis away from essential conceptual features toward specific works. If an impeachable offense is whatever Congress says it is, then one might suggest that a Theory of the Earth is whatever a historical actor regarded as such. Identification of Theories of the Earth may largely be delegated to the actors themselves.

It may be objected that such a demarcation will be broader than the works actually read by any single actor. Indeed, a diverse textual tradition is more like a great ballroom than a quiet evening alone; although many turn out, not even the host will dance with every partner in the room. For this reason a historian of the dance should err on the side of inclusion, if a selection bias is inevitable. This becomes especially obvious when a few partners make a show of refusing to dance with others, or attempt to persuade the band to strike up a polka instead of a waltz. Rhetorical disputes over the demarcation of the tradition by Bourguet and others were repeatedly constitutive of the tradition.

A more serious objection is that the delegation to historical actors of the task of identifying Theories of the Earth might hold our interpretations hostage to the opinions of the actors themselves. But there is much more interesting work awaiting the historian than debating actors on their own terms. No longer is it entirely relevant even to ask with the actors, "Is this a Theory of the Earth?"; for our most important questions now move back a level, out of the agonistic field in which the actors debated which works were Theories of the Earth, and what the ideal, future "theory" of the Earth might be, into a broader, historical, meta-view that attends to the character of such contests themselves. We may safely leave to philosophers questions as to whether any historical figure cited by Bourguet or others was "actually" a Theorist of the Earth. For the historian such identity disputes may properly remain unresolved, or at least ambiguous. A contested tradition defies formulaic definition, which should never substitute for historical interpretation. Instead of devoting our time and space to arguments over whether a given work qualifies in fact as a Theory of the Earth, we may move on to questions of the relations between textual and technical practices, and of participation in a tradition through its ongoing appropriation and transformation.

§ 8. Reassessing the Historiography of Theories of the Earth

The historiography of Theories of the Earth has been dominated by two powerful perspectives, both of which have obscured much about the tradition even while they have revealed important insights. Both chronologically and by subject matter, Theories of the Earth fall in a no man's land between cosmology and historical geology. They have been interpreted from these two standpoints either as the consequence of large-scale changes in cosmology during the seventeenth-century Scientific Revolution or as the misguided endeavor that was happily displaced by the emergence of geology in the early nineteenth century. Unfortunately, both perspectives have failed to do justice to the historical complexity of this contested textual tradition.

To remedy this situation monographs devoted to particular Theorists, specific localities, and short-term problems alone will not be enough; if historians are to break away from uncritical, tacit adoption of these two "big pictures," thematic interpretations of the tradition over a longer duration are imperative. Such reassessments have already begun. In 1987, Rachel Laudan advanced a bold series of provocative theses regarding the significance of eighteenth-century German and Scandinavian mineralogical traditions for the emergence of historical geology.[383] Recently complementing Laudan's work, and more nuanced in historical analysis, Rhoda Rappaport fills in a remarkable portrait of the ways the framework of geological thinking by French, English and Italian savants through the first half of the eighteenth century was shaped by historical scholarship.[384] Although both Laudan and Rappaport are concerned with broader professional, institutional and national settings rather than Theories of the Earth, Kenneth L. Taylor has reflected on the ramifications of revisionist interpretations for conventional views of Theories of the Earth *per se*. After analyzing the historiography that has plagued understanding of Theories of the Earth by characterizing them as a speculative endeavor, Taylor concludes:

> I began to see that it was not only Desmarest's interpretations of his geological observations that were informed by theories of the Earth; so also were the very sorts of things he thought it worth observing. This in turn made it apparent that the distinctions between the traditional theories of the Earth and the new ideas out of which geology was being formed were far more blurred than I had expected. In time I came to the view that the theories of the Earth, far from being sterile notions which had to be jettisoned before any constructive scientific changes could occur, were apparently among the sources out of which those changes came. Theories of the Earth, Lyell to the contrary, did not divert attention from study of the laws of nature; they actually encouraged active pursuit of natural laws suitable to an understanding of the Earth. Now I think of Desmarest as one of many geological characters in the second half of the eighteenth century whose contributions toward creation of a modern geological outlook were made as much within the context of theories of the Earth as in a posture of rebellion against them, possibly more so.[385]

[383]Laudan, *From Mineralogy to Geology.*

[384]Rappaport, *When Geologists were Historians*.

[385]One might add that a posture of sustained *indifference*, rather than rebellion, would represent a more significant decline in the dialectical development of a heterogenous tradition. Kenneth L. Taylor, "The Historical Rehabilitation of Theories of the Earth," *The Compass: Earth Science Journal of Sigma Gamma Epsilon* 69 (1992): 334–345, quote on p. 341. My entire analysis of Theories of the Earth as something other than a speculative genre owes its inspiration to this seminal paper.

On the foundation of this scholarship, with an increased appreciation for Theories of the Earth as a contested textual tradition, it now appears that the dialectic between natural order and historical contingency provides one promising theme for interpreting Theories of the Earth over the *longue durée*. However, before any reassessment of the roles of historical contingency and natural order in Theories of the Earth is possible, historiographical principles underlying contrary "big picture" interpretations must be addressed, a task which occupies the following two chapters.

CHAPTER 2 On the Boundaries of Cosmology

§ 1. Cosmological Frameworks and World Views

No one would deny that relations between cosmology and Theories of the Earth were intimate, whether one considers common topics or deeper themes and perspectives. Some sense of the possible overlap of topics in cosmology and Theories of the Earth has already been suggested.[1] In a classic survey, Katherine Collier surveyed the beliefs of a variety of Theorists regarding cosmological topics such as the structure and nature of the heavens, celestial influences, primeval light, the natural place or distribution of elements, and the growth of metals.[2] Many topics traditionally considered part of cosmology were prominent in

1 See the section entitled "Cosmogony," beginning on page 124, and note the plates from John Hay's Theory of the Earth (Figure 9 on page 129 through Figure 18 on page 138).

2 Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries*, New York: Columbia University Press, 1934 (reprinted New York: Octagon Books, 1968).

Theories of the Earth, including the shape or figure of the Earth; the original formation of the Earth, Moon, solar system, or universe; the mutual relations of the Earth and Sun; the action of comets in the solar system; the interior of the Earth; and the possible existence of a plurality of worlds or the habitability of other planets.

In addition to commonplace topics, broader cosmological frameworks or "world-views" offer opportunities to discern deeper relations between cosmology and Theories of the Earth. Unfortunately, historians interpreting Theories of the Earth along worldview lines have confined their attention to only two major frameworks: Copernican cosmology and the mechanical philosophy. Alternative seventeenth-century cosmologies, including Stoic, magnetic, chymical and later scholastic philosophies, have largely been discounted (perhaps because many of them were geocentric), although they were of critical significance for seventeenth-century thinking about the Earth.

The Copernican Revolution provided the context for early interpretations of Theories of the Earth as manifesting a change from the anthropocentric Aristotelian cosmos to the objective universe of Galilean physics. Collier's study interpreted changes in conceptions of the Earth as due to the shift from a geocentric Ptolemaic cosmos to a geokinetic Copernican universe. Marjorie Hope Nicolson explored the consequences for an aesthetics of the Earth resulting from the dissolution of the finite and hierarchical medieval cosmos and the construction of an infinite Newtonian universe.[3] Most influentially, Jacques Roger asserted that Copernicanism was an essential precondition for the rise of Theories of the Earth because the latter were literally inconceivable apart from the conceptualization of the Earth as a planet:

> By making the earth a simple planet which turned like others around the sun, the new astronomy freed the earth from the weight of the cosmos, whose center it had been for so long. From then on, it could be studied for itself, and its history became independent of that of the universe. Thus it was during the seventeenth century that a new area of science appeared, the Theory of the Earth.[4]

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[3] Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca: Cornell University Press, 1959).

Each of these arguments were congenial to then-current characterizations of the Copernican Revolution and remain widely accepted today.

The seventeenth-century triumph of mechanical philosophy once served as a defining theme of the Scientific Revolution. It also provided an important cosmological backdrop for interpreting Theories of the Earth, because cosmologies and matter theories often develop hand-in-hand as ways of thinking about the very large and the very small proceed in tandem. Seventeenth-century views of an infinite universe were to a great extent associated with an atomic or corpuscularian philosophy of matter in motion. John C. Greene emphasized how the mechanical philosophy of a lawbound system of matter in motion led to a world-view of directional change, displacing the static Elizabethan world-picture. The latter, arguably the dominant view of nature in the seventeenth century, featured stability and permanence, balance and design. However, according to Greene, another view of nature as a "law-bound system of matter in motion" was "incipient" in the seventeenth century but "eventually emerged dominant itself" in the nineteenth century:

> In some respects the mechanical cosmology bore the imprint of the dominant view of nature. Newton's impenetrable atom was an example *par excellence* of a permanent structure that participated in the world of change without being altered thereby.... But however immutable the atom might be, the idea that visible nature is produced by the combinations and permutations of a system of material particles in motion had disturbing implications for the dominant view of nature.... There was nothing in the idea of a law-bound system of matter in motion to suggest the stability of the structures produced by its functioning. *Mutability, not stability, was the logical outcome of such a system*, and, since every state of the system proceeded by rule from the preceding state, it was hard to see why any state should be regarded as initial or as final.[5]

Greene argued that ideas of temporal change were inherent in the mechanical philosophy, which undermined conceptions of the stability or perpetuity of specific structures (by implication including such structures as mountains or the Earth).

[4] Jacques Roger, *Buffon: A Life in Natural History*, trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997), 94. This comment occurs in a chapter which recapitulates some of the claims defended in Jacques Roger, "La Théorie de la Terre au XVIIe Siècle," *Revue d'Histoire des Sciences* 26 (1973): 23–48.

David Kubrin analyzed Theories of the Earth as the expression of a tension between the mechanical philosophy and providential views of the natural order. Kubrin's valuable study refutes the unfortunately still widespread impression that Theories of the Earth were exclusively Cartesian, and in method or metaphysics somehow incompatible with the "Newtonian world-view." Against another widespread misperception, Kubrin also amply documented that writers of Theories of the Earth were motivated by more than the desire "to make scientifically respectable the traditional picture of the Creation and deluge presented in Genesis."[6] These two theses make his study of continuing importance. However, Kubrin, like Richard Westfall, discerned an inherent contradiction between the mechanical philosophy and early modern doctrines of providence.[7] Although this alleged contradiction set the stage for Kubrin's metaphysical analysis, its historical validity has been undermined by recent studies of providence and the mechanical philosophy.[8] Furthermore, according to Kubrin there was a consonance on a deep, world-view level between the mechanical philosophy and the doctrine of the eternity of the world. Kubrin identified as his "central theme" the "role played in seventeenth century English religious and scientific thought by the doctrine of the world's eternity."

5 John C. Greene, "Objectives and Methods in Intellectual History," *The Mississippi Valley Historical Review* 44 (1957): 58-74; reprinted in *Science, Ideology, and World-View: Essays in the History of Evolutionary Ideas* (Berkeley: University of California Press, 1981), 13–14, italics added. Cf. John C. Greene, *The Death of Adam: Evolution and Its Impact on Western Thought* (Ames, Iowa: Iowa State University Press, 1859). The classic study is Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936), which is nicely complemented by Tillyard's exploration of the static idea of order in the sixteenth and seventeenth centuries; E. M. W. Tillyard, *The Elizabethan World Picture* (New York: Vintage Books, Random House, n.d).

6 David Charles Kubrin, "Providence and the Mechanical Philosophy: The Creation and Dissolution of the World in Newtonian Thought. A Study of the Relations of Science and Religion in Seventeenth Century England" (Ph.D. dissertation, Cornell University, 1968), x.

7 Cf. Richard S. Westfall, *Science and Religion in Seventeenth-Century England* (New Haven: Yale University Press, 1958; reprinted Ann Arbor: University of Michigan Press, 1973); and Richard S. Westfall, "The Rise of Science and the Decline of Orthodox Christianity: A Study of Kepler, Descartes, and Newton," in *God and Nature: Historical Essays on the Encounter between Christianity and Science*, ed. David C. Lindberg and Ronald L. Numbers (Berkeley: University California Press, 1986), 218–237.

8 Cf. Francis Oakley, *Omnipotence, Covenant, and Order: An Excursion in the History of Ideas from Abelard to Leibniz* (Ithaca: Cornell University Press, 1984); Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994); R. M. Burns, *The Great Debate on Miracles from Joseph Glanville to David Hume* (London, 1981).

His chief premise was that “the very fact that scientific laws know no temporal limitations made the task of the cosmogonists [in refuting the eternalists] next to impossible.”[9] This metaphysical claim undergirds his analysis at every step. Like Greene, Kubrin interpreted Theories of the Earth as a manifest working out of the implications of the mechanical world-view with its atemporal laws, but for Kubrin acceptance of such laws pushed the development of thought toward eternalistic cosmologies whereas for Greene they led to mutability of structures and directional change.[10]

[9] Kubrin, “Providence and the Mechanical Philosophy,” xi. Bracketed words are mine.

[10] Given Kubrin’s perspective, one might ask, if the mechanical philosophy worked to push thinking about the Earth in the direction of eternity and physical necessity, then how could the directionalism of many Theories of the Earth have developed as a result of the same mechanical philosophy? This suggests that additional factors were involved, such as the contextual prerequisite suggested by Roger’s second criterion (discussed in the next section).

§ 2. Roger's Demarcationist Criteria: Global Directionalism

Perhaps the most sophisticated and thoroughgoing attempt to interpret Theories of the Earth in light of cosmological themes is an indispensable essay by Jacques Roger.[11] In this insightful and enormously influential article Roger defined Theories of the Earth on conceptual grounds as possessing two essential characteristics: first, they considered the structure and genesis of the globe as a whole[12]; and second, they organized general phenomena of the Earth into a *history* wherein "history" is understood as an irreversible chronological succession of events.[13] We may refer to these two defining characteristics as Roger's *Global* and *Directionalist* criteria (Table 25). As noted above, Roger argued that the ability to conceptualize the globe as a whole was made possible by the Earth's new planetary status resulting from the Copernican Revolution.[14] On the other hand, Roger suggested that historical conceptions of an irreversible history were made possible by the role of the Bible in early modern culture, particularly the first chapters of Genesis.[15] According to Roger the first criterion excludes studies of a specific locality or region of the Earth, and the second criterion excludes nondirectionalist perspectives of geohistory.[16]

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[11] Jacques Roger, "La théorie de la terre au XVIIe siècle," *Revue d'Histoire des Sciences*, 1973, 26: 23–48.

[12] "La première caractéristique de la théorie de la Terre, c'est donc de considérer la structure du globe comme un tout, et la genèse de cette structure comme une série de phénomènes généraux, intéressant la totalité de la Terre." Roger, "La théorie de la terre," 26.

[13] "Le second caractère de la théorie de la Terre, et sans doute le plus important, est d'être une histoire générale du globe, ordonnant les phénomènes les plus généraux dans une succession chronologique irréversible." Roger, "La théorie de la terre," 29.

[14] Writing of "La première caractéristique..." Roger wrote: "Sur ce point, la théorie de la Terre n'a été rendue possible que par la révolution héliocentrique." Roger, "La théorie de la terre," 26. This contextual prerequisite is criticized at length in the remainder of this chapter.

[15] Roger commented that "pour le XVIIe siècle, le récit mosaïque était le seul modèle possible d'une histoire de l'univers et de la Terre...," Roger, "La théorie de la terre," 32. This thesis is clarified and developed with respect to hexameral idiom throughout this dissertation.

[16] Both of these implications are dubious, as the following paragraphs suggest. Attempts to define Theories of the Earth by means of essential concepts are criticized in Chapter 1.

TABLE 25. Roger's definition of Theories of the Earth (1973)

Criteria	Contextual prerequisites	Exclusions
Global	Copernican cosmology	Regional studies
Directionalist	Biblical interpretation	Cyclical, steady-state, and eternalistic systems

Although Roger's analysis is supported by great erudition and seems almost enchanting in its intrinsic coherence and intelligibility, it is an exercise in demarcation that is ultimately philosophical rather than historical. In contrast to Roger's Directionalist criterion Kubrin, despite his metaphysical mode of analysis, admitted Theorists with cyclic and dynamic perspectives of Earth history as participants in a common debate along with Theorists who envisioned unique successions of particular events. Moreover, Buffon's initial "Théorie de la terre" (1749) envisioned cyclic revolutions, as Roger acknowledged, a significant exception which by itself provides sufficient reason to reject an essential Directionalist criterion, if not the demarcationist agenda altogether. If Buffon's cyclic "Théorie de la terre" is regarded as a Theory of the Earth (as textual criteria require) then one may no longer exclude the works of Athanasius Kircher and others solely on account of their similarly non-directionalist vision.[17]

In contrast to Roger's Global criterion, regional studies and the Theory of the Earth tradition were not mutually exclusive. It was perfectly possible to regard a specific locality or region as a microcosm of the globe, manifesting phenomena which provide unrivalled insight into the processes and structure of the Earth as a whole.[18] Consider the example of Louis

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[17] Buffon's account of the formation of the planets in the same volume was indeed directionalist. Roger repeatedly pointed out the irony of Buffon's combining a directionalist account of cosmology with a cyclic view of the Earth's past; see chapters 7 and 8 of Jacques Roger, *Buffon: A Life in Natural History*, trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997). See "Ornamental Global Views in Buffon's Histoire naturelle," beginning on page 379. Roger argued that Kircher's *Mundus subterraneus* (1664) was not a Theory of the Earth because of its Aristotelian nondirectionalism, despite Kircher's distinction between antediluvian and postdiluvian worlds. Roger, "La théorie de la terre," 30. See "Kircher's Encyclopedia of the Earth," beginning on page 527. Chapter 3 explores how similar problems arise when attempts are made to exclude Theorists such as Hooke, Halley, Maillet, or Hutton.

Agassiz encamped on the glaciers of Switzerland. Roderick Murchison criticized Agassiz's work precisely on the grounds of its global implications:

> Once grant to Agassiz that his deepest valleys of Switzerland, such as the enormous Lake of Geneva, were formerly filled with snow and ice, and I see no stopping place. From that hypothesis you may proceed to fill the Baltic and the northern seas, cover southern England and half of Germany and Russia with similar ice sheets....[19]

The same was the case for Kircher in Sicily,[20] Steno in Tuscany,[21] Hooke on the Isle of Wight,[22] De Maillet in Egypt,[23] Werner in Saxony,[24] Hutton at Siccar Point or Jedburgh, Scotland,[25] Hamilton in Italy,[26] Pallas in Siberia,[27] Whitehurst in Derbyshire,[28] Cuvier in

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[18] The misnamed "Copernican cosmological principle" is analogous to Theorists' use of local observations to generalize about the Earth as a whole. This often-hailed assumption of modern cosmology stipulates that the Earth's present location in the universe is typical in the sense that generalizations about the universe as a whole may be made on the basis of "local" (Earthbound) observations of redshift, cosmic background radiation, etc. This and other assumptions also allow scientists studying the very small in restricted places such as CERN or Fermilab to contribute to a science of the universe as a whole.

[19] Quoted by Carozzi in the introduction to Louis Agassiz, *Studies on Glaciers preceded by the Discourse of Neuchâtel*, trans. and ed. Albert V. Carozzi (New York: Hafner Press, 1967), xxix-xxx. On Agassiz's crusade for an Ice Age see Anthony Hallam, *Great Geological Controversies,* 2d ed. (Oxford: Oxford University Press, 1989), chapter 4. Agassiz is not usually regarded as a Theorist of the Earth, but Carozzi concedes that Agassiz's *Études sur les Glaciers* (1840) "combines accurate personal observations of many Alpine glaciers with unexpected conclusions of *cosmic* proportions. These far-reaching statements should have discredited the book, but under the unusual conditions which seem to have characterized most of Agassiz's achievements, they turned out to be the major asset of the work." Louis Agassiz, *Studies on Glaciers*, v (italics added). Although he later adopted Agassiz's Ice Age theory with apologies, in 1837 Alexander von Humboldt criticized it as resembling a system of the Earth: "I think that you should concentrate your moral and also your pecuniary strength upon this beautiful work on fossil fishes. In so doing you will render a greater service to positive geology, than by these general considerations (a little icy besides) on the *revolutions of the primitive world*, considerations which, as you well know, convince only those who give them birth." Quoted in Carozzi, xxii (italics added). Hallam notes (p. 99) that "Far from being subdued by his critics, Agassiz exported the glacial theory to North America after his arrival there in 1846, applying it to the phenomena in the White Mountains of New Hampshire and the Great Lakes. Initially he found only a few converts, but this did not deter him from developing increasingly extravagant views as the years passed, eventually arguing not only for a single ice sheet extending from the Arctic but for an ice-fill even in the Amazon valley!"

[20] See quote in "Kircher's Encyclopedia of the Earth" on page 529.

[21] See quote in "Steno's Tuscan Autopsy" on page 569.

[22] For Hooke's study of the geological phenomena of the Isle of Wight see Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford: Oxford University Press, 1996), chapter 2.

[23] "Moreover, you are right here in Egypt, where the features in favor of my system are so remarkable that no other country in the world displays more striking ones." Benoît De Maillet, *Telliamed: Or Conversations Between an Indian Philosopher and a French Missionary on the Diminution of the Sea*, trans. and ed. Albert V. Carozzi (Urbana: University of Illinois Press, 1968), 58.

[24] Contrast William Phillips' remarks about Werner's "large and important district" (quoted in footnote 103 on page 56) with Lyell's quote on page 331. Ospovat provides an important clarification regarding the basis for Werner's extrapolation of local formations to distant regions, noted below on page 711.

the Paris basin,[29] Amos Eaton in New York,[30] William Dawson in Nova Scotia,[31] William Phillips in the English plains,[32] *et al.* None of these investigators hesitated to affirm the global significance of their regional observations. Indeed, for this reason the narratives of observant travellers on voyage or expedition to unfamiliar regions were long regarded as a mainstream genre for publications of geological interest.[33] Interestingly, the same point can be made visually from various works related to the Theory of the Earth tradition, for repeated juxtapositions of regional depictions with global sections and views confirms the impracticality of maintaining a strict exclusion of regional studies from global perspectives (Table 26).

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[25] Hutton's observations at Jedburgh are discussed in "Hutton and the Whig Interpretation of Geology," beginning on page 269.

[26] See Hamilton's quote on page 164.

[27] See discussion of Pallas' travels on page 265.

[28] Although the Book of Nature lies "open to all men," Whitehurst announced that this was "perhaps in no part of the world more so than in Derbyshire." John Whitehurst, *An Inquiry into the Original State and Formation of the Earth; Deduced from Facts and the Laws of Nature. The Second Edition, Considerably Enlarged, and Illustrated with Plates*, 2d ed. (London: Printed for W. Bent, Pater-Noster Row, 1786), preface, first page (not numbered). On Whitehurst cf. page 283 and "Whitehurst's Enigma," beginning on page 668.

[29] See the discussion of Cuvier and the Paris Basin beginning on page 307.

[30] See "Amos Eaton, Fieldwork, and Wernerian Geognosy," beginning on page 695.

[31] Dawson's "Amerocentrist" Acadian geology is discussed in Susan Sheets-Pyenson, *John William Dawson: Faith, Hope, and Science* (Kingston and Montreal: McGill-Queen's University Press, 1996), 112 and ch. 8.

[32] "Few of us have visited other countries; not many have seen the more mountainous parts of our own; scarcely one present, perhaps, knows the internal history of the spot which now supports him.... It seems to me that we cannot do better than begin our inquiries into the nature of such countries as those in which we live—of low and level countries;.... within the present century, considerable attention has been given to the exploring of some tracts of level country, which have amply paid the research. From the actual nature of these, we may reason by analogy of the rest." William Phillips, *An Outline of Mineralogy and Geology*, 70-71. Phillips was not regarded as a Theorist of the Earth, but the inclusion of geologists as well as Theorists of the Earth in this litany does not weaken the objection to an exclusive globalist criterion. One geology-observer has drawn an analogous conclusion which makes an interesting historical thesis: "Because geology is sometimes intuitive even to the point of being subjective, the sort of field experience one happens to acquire may tend to influence one's posture with regard to deep questions in the science. Geologists who grow up with young rocks are likely to subscribe strongly to the doctrine of uniformitarianism, whereby the present is seen to be the key to the past.... Geologists who grow up with very old rock tend to be impressed by the fact that it has been around since before the earliest development of life, and to imagine a progression in which the recycling of the earth's materials is a subplot in a dramatic story that begins with dark scums in motion on an otherwise featureless globe...." John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), 168.

[33] Cf. the remark by de la Beche on page 333 about new countries being explored. For brief comments on travel reports and geological reconnaissance, see "Hamilton and Literary Genres of Theories of the Earth," beginning on page 159.

TABLE 26. Correspondence of Global and Local illustrations

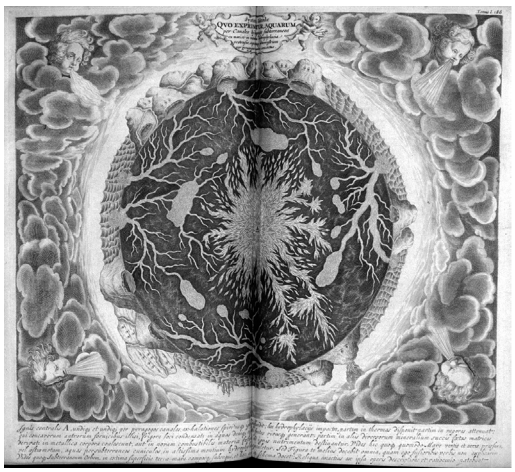
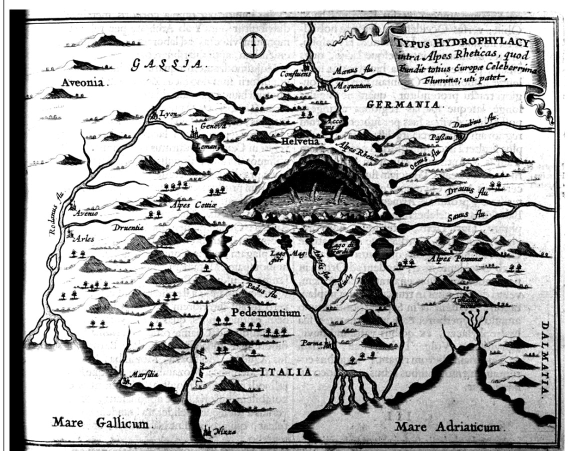
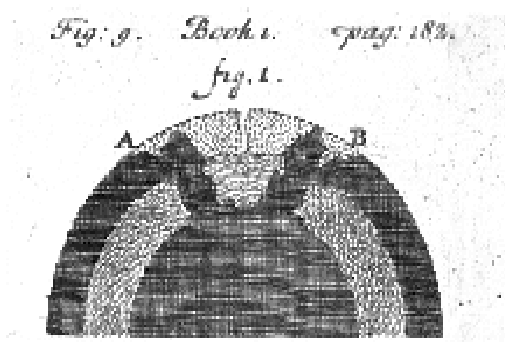
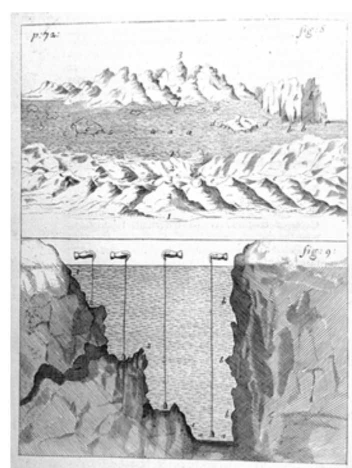
<table>
<tr><th>Global section or view</th><th>Regional or local representation</th></tr>
<tr><td></td><td>
</td></tr>
<tr><td colspan="2">Athanasius Kircher, Mundus subterraneus, 1665. Kircher suggested that water circulates within the Earth as shown on the left. Compare the section of a type-mountain in the Alps (right) with one of the mountains near the top of the global section (left). Kircher's work is a virtual museum of illustrations ranging the continuum from global sections to regional and local representations. See "Kircher's Encyclopedia of the Earth," beginning on page 527.</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td colspan="2">Thomas Burnet, Theory of the Earth, 1684. The diagram on the right, adapted from Kircher, corresponds to the coastal areas A and B on the global hemisection (left), representing the formation of ocean shorelines and island chains after the exterior crust collapsed into the watery abyss (which caused the Deluge). See "Textual Assimilation: The Sacred Theory of Burnet," beginning on page 431.</td></tr>
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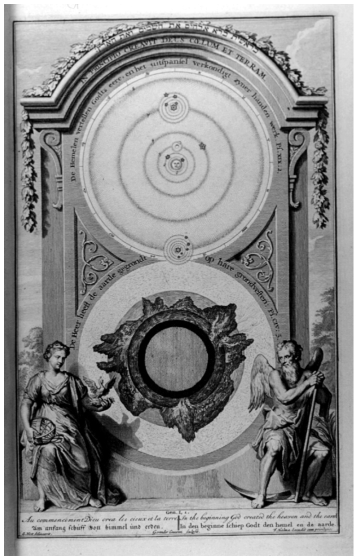
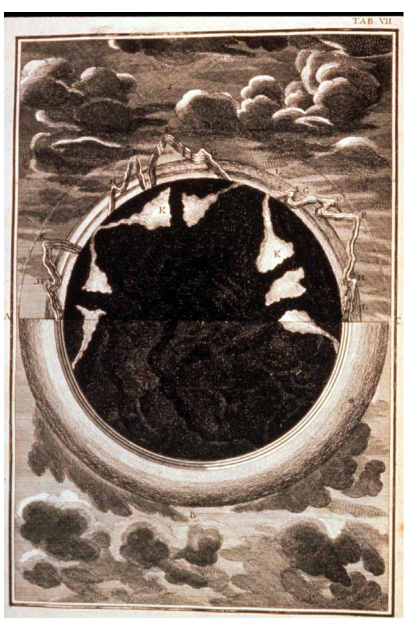
TABLE 26. Correspondence of Global and Local illustrations

<table>
<tr><th>Global section or view</th><th>Regional or local representation</th></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Biblical illustrations for the creation week (left) and the Garden of Eden (right) by Hoet (1728). Events of the creation week and the Garden of Eden were frequently cited in early modern thinking about the Earth. Note that both illustrations imply that mountains originated before the Deluge. See "Hexameral Tradition and Global Illustrations," beginning on page 518.</td></tr>
<tr><td>
</td><td>
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<tr><td colspan="2">Johann Jakob Scheuchzer, Physica Sacra, 1731–1735. Both diagrams represent the third day of creation and the emergence of dry land. The global section is actually flanked by two landscape scenes, only one of which is shown here. Most of Scheuchzer's hexameral plates are reproduced in the Appendix.</td></tr>
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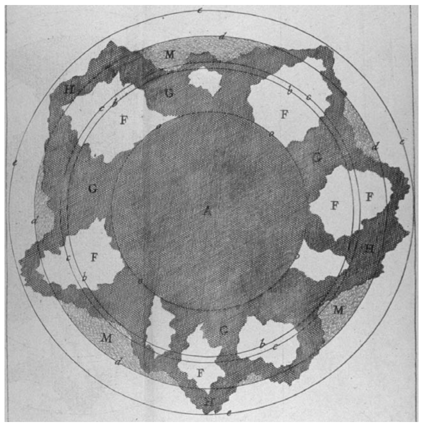
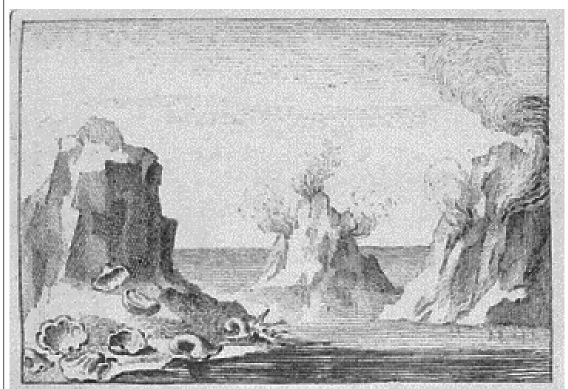
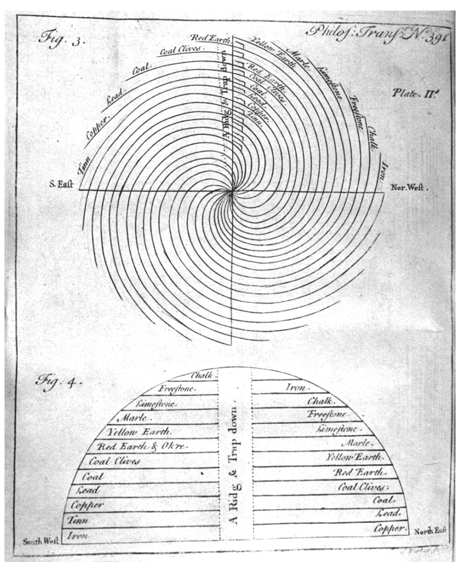
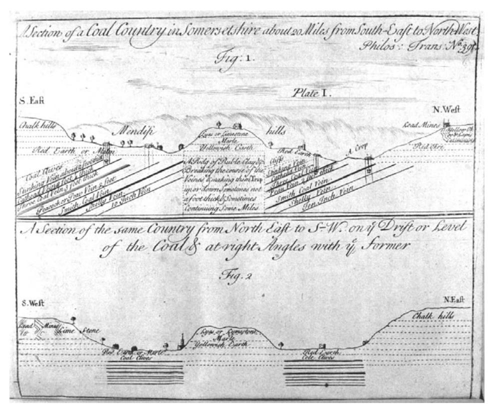
<tr><td></td><td></td></tr>
<tr><td colspan="2">Anton Lazzaro Moro, De crostacei, 1740. The islands rising from the sea (right) correspond to the crust emerging above sea level due to subterraneous heat expansion (left). See “ Moro's Ultra-Volcanism,” beginning on page 664.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">In the Philosophical Transactions (1725), John Strachey inferred the natural order of strata within the Earth (left) on the basis of local sections and coal mining observations (right). See page 659ff.</td></tr>
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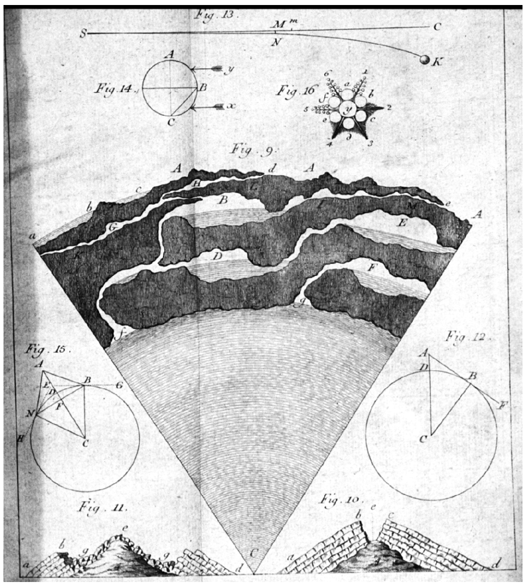
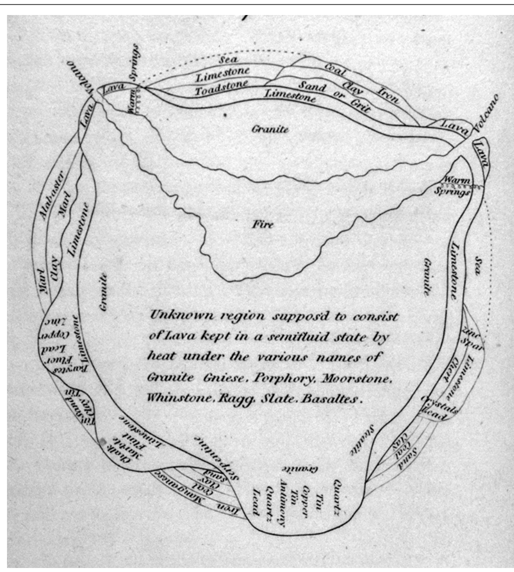
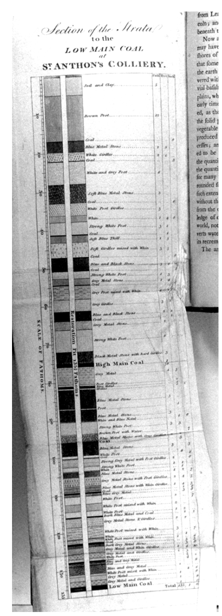
TABLE 26. Correspondence of Global and Local illustrations

Global section or view	Regional or local representation
	
Johann Esias Silberschlag, Geogenie, 1789, global section Tab VI (left) and Tab II (right). Silberschlag related his ideas for the cause of the Deluge to a cavernous Earth and central watery abyss, where present-day springs disclose the operation of the fountains of the deep. See "Silberschlag, Caverns, and German Romanticism," beginning on page 687.	
	Erasmus Darwin, The Botanic Garden (1790). Darwin relied upon stratigraphical inferences drawn from area coal mines (right) as the basis for his global section (left). See " Erasmus Darwin's Botanic Garden, " beginning on page 674. 

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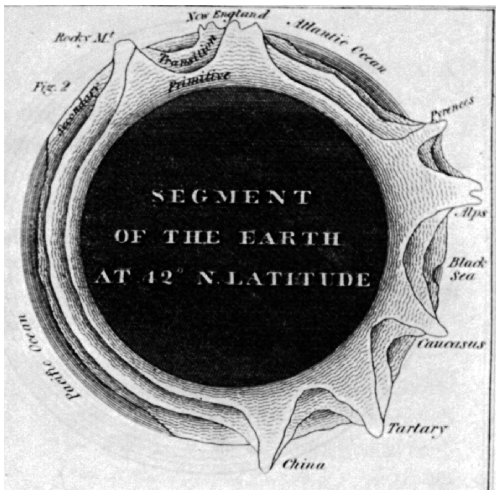
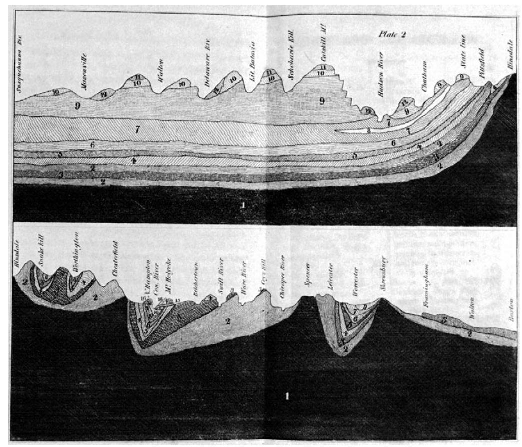
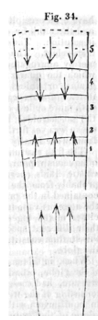
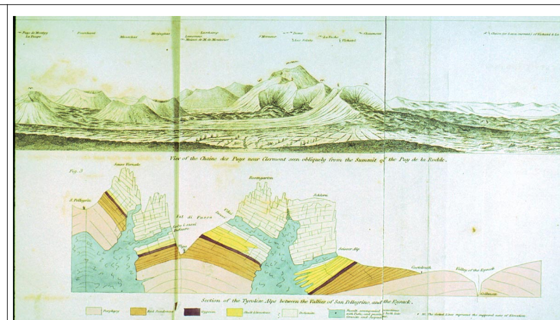
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Amos Eaton's many global sections (left, 1820) were correlated with the results of his own fieldwork in New England (right, 1820). See "Amos Eaton, Fieldwork, and Wernerian Geognosy," beginning on page 695.</td></tr>
<tr><td>George Poulett Scrope, Considerations on Volcanos (1825), included this schematic, partial global section depicting the original formation of the various strata. See "Scrope's Vulcanist Cosmogony," beginning on page 681.

</td><td></td></tr>
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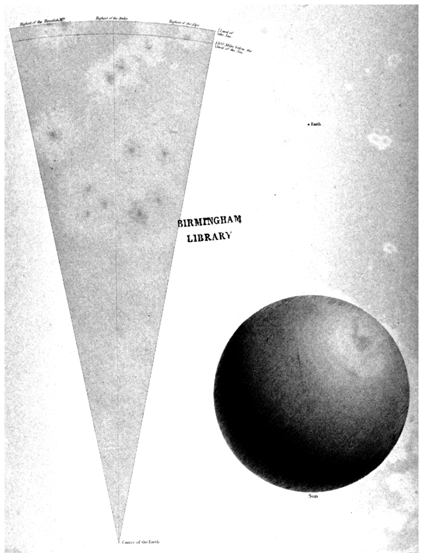
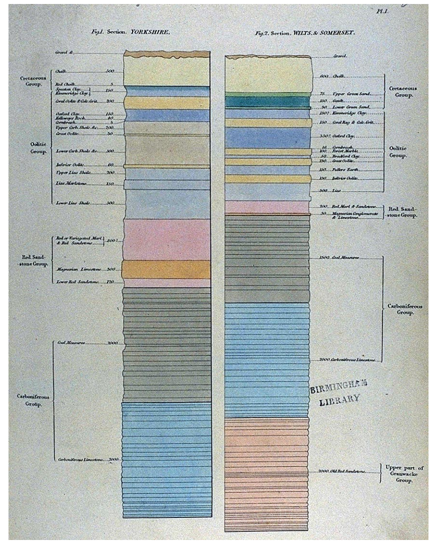
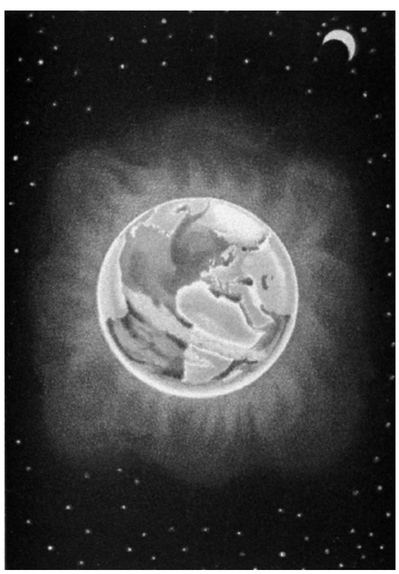
<tr><td></td><td></td></tr>
<tr><td colspan="2">The global section and view (left) of Henry Thomas de la Beche, Sections and Views (1830), illustrates the thinness of the Earth's outer crust and surface irregularities relative to the Earth as a whole. Yet this thin area is all that may be known on the basis of local sections such as the one shown on the right. See "Visual Texts," beginning on page 715.</td></tr>
<tr><td rowspan="2"></td><td></td></tr>
<tr><td>Arnold Guyot's Creation, or, The Biblical Cosmogony in the Light of Modern Science (1884) contains a series of plates comprised of views from space and prehuman landscapes. In these two examples Guyot correlated the disappearing photosphere of the Earth (left) with the coming of the Silurian Age (right). See "From Genesis to History: Arnold Guyot, James Dana, and Hexameral Geology," beginning on page 736.</td></tr>
</table>

The ahistorical character of Roger's demarcation attempt becomes apparent when one observes that in tandem his two conceptual criteria exclude the works of Kircher (whose Earth was steady-state), Maillet and Hutton (both of whose Earths passed through dynamic cycles), Steno (whose focus was the region of Tuscany),[34] and even Descartes (who provided a genetic causal account of planetary formation as a repeatable and predictable process rather than an irreversible history of the Earth in particular). Indeed, in a later article which notably diverged from his first analysis, Roger addressed this contrast between Descartes and later Theorists, crediting Burnet rather than Descartes with establishing a truly historical rather than merely genetic account of the Earth.[35] Nevertheless, in their own time works such as these were perceived as contributing to a common debate involving shared sets of questions, among which were the age or history of the Earth and the significance of particular regions, or natural processes evident on a regional scale, for the understanding of the globe. On each question the competing perspectives were numerous and at every step the proper shape of the developing tradition was intensely contested.

[34] Cf. "Kircher's Encyclopedia of the Earth," beginning on page 527; "Marginality and Mentalité," beginning on page 335 (De Maillet); "Hutton and the Whig Interpretation of Geology," beginning on page 269; and "Steno's Tuscan Autopsy," beginning on page 562.

[35] Jacques Roger, "The Cartesian Model and Its Role in 18th-century Theory of the Earth," in *Problems of Cartesianism* (Kingston: McGill-Queen's University Press, 1982), 95–112. Bourguet's conclusion that Burnet rather than Descartes was the founder of the tradition, noted above on page 195, is not cited by Roger, whose similar conclusion was based on different grounds. Roger's revised position is clarified and defended in "Baptizing Descartes," beginning on page 602.

§ 3. Case 1: The Meteorological Tradition

"Cosmology" has sometimes served as a convenient label for any topic or tradition that does not seem recognizably geological or stratigraphical.[36] At various times considerations of a more astronomical, planetary, geophysical, meteorological, or hexameral character have been lumped together as cosmology. For this reason it is not surprising that seventeenth-century meteorological and hexameral considerations, although of critical significance for Theories of the Earth, became later regarded as objectionable cosmological baggage and were cited to discredit the tradition as incurably cosmogonical. This section therefore explicates how the meteorological tradition related to Theories of the Earth in a way that was not exclusively cosmological any more than it was purely geological, and the next section makes a similar point with respect to one specific topic, the Earth's center of gravity.

§ 3-i. The Place of Meteorology: Aristotle and Descartes

TABLE 27. Order of the Sciences: Aristotle and Descartes

	Aristotle	Descartes
Metaphysics	Metaphysics	Principia, Part I Metaphysics
Physics	Physics	Principia, Part II Physics
Cosmology and matter theory	On the Heavens Generation and Corruption	Principia, Part III Cosmology
Meteorology	Meteorology	Principia, Part IV of the Earth Les Météores
Animals	History of Animals, Parts of Animals, Generation of Animals, On the Soul	L'Homme

What was the relationship between cosmology and meteorology in the natural philosophies of Aristotle and Descartes? As is well known, Descartes (like Petrus Ramus, Francesco

[36] A typical example is Carozzi's reference in footnote 19 on page 213 to Agassiz's theory of the Ice Age as "cosmic" because it implied occasional interruptions in the general pattern of global cooling. The definition of cosmology as that-which-is-not-geology is both an observers' and an actors' category; similar usages are often found in the writings of nineteenth-century geologists.

Patrizi, or Francis Bacon before him) presented his system as an alternative to Aristotle *en toto*. Interestingly, the Aristotelian *corpus* of natural philosophy may be arranged in a progression of topics resembling the organization of Descartes' *Principles of Philosophy* (Table 27). A reader of Aristotle may begin with principles of human knowledge (*Metaphysics*), then move on to physics (*Physics*), cosmology (*On the Heavens*), and sublunar matter theory or change in general (*Generation and Corruption*). Next, in a work that constitutes his own theory of the Earth, Aristotle concluded his inquiries into physical nature with the *Meteorology*:

> We have already dealt with the first causes of nature [*Metaphysics*] and with all natural motion [*Physics*]; we have dealt also with the ordered movements of the stars in the heavens [*On the Heavens*], and with the number, kinds, and mutual transformations of the four elements, and growth and decay in general [*Generation and Corruption*]. It remains to consider a subdivision of the present inquiry [i.e., physical nature] which all our predecessors have called Meteorology. Its province is everything which happens naturally but with a regularity less than that of the primary element of material things [*aither*], and which takes place in the region which borders most nearly on the movements of the stars.[37]

Thus Aristotle situated meteorology with respect to the previous inquiries in two ways; first, by stipulating its sublunar subject matter and, second, by noting a relative lack of intelligibility due to the inherent instability of sublunar nature. The subject matter of meteorology, for Aristotle, included not only comets, the Milky Way, shooting stars, rainbows, winds, storms, various forms of precipitation, and other phenomena which he regarded as atmospheric, but also earthquakes, the ebb and flow of the seas or tides, marine fossils located far from present shores; or generally, "all phenomena that may be regarded as common to air and water, *and the various kinds and parts of the earth and their characteristics*."[38] All of these phenomena were

[37] Aristotle, *Meteorology*, I.I; Aristotle, *Meteorologica*, trans. H. D. P. Lee, Loeb Classical Library, no. 397 (London: Heinemann, 1952), 5. Explanatory notes added in square brackets are mine.

[38] Aristotle, *Meteorology* I.I; trans. Lee, 5; italics added. Aristotle went on to add that the subsequent area of inquiry would consider plants and animals, situating his meteorological theory of the Earth as a prelude to his biological corpus, e.g., *History of Animals, Parts of Animals, Generation of Animals* (p. 7). Similarly, Descartes pressed on from his Theory of the Earth to account in his drafts of *The Treatise on Man* (1647-48) for animate creatures on the basis of his mechanical philosophy, e.g., delving into the circulation and action of the heart, a topic already emphasized as sequential to the Theory of the Earth in his *Discourse on Method* (1637). See footnote 379 on page 619.

explained by Descartes as well; those "common to air and water," including the rainbow, in *Les Météores*, the meteorological treatise attached to his *Discourse on Method* (1637),[39] and those of "the various kinds and parts of the earth" in the Theory of the Earth of Part IV of the *Principles of Philosophy*.

As we have seen, many topics investigated in Aristotle's *Meteorology* are those one might expect in a theory of the Earth.[40] Aristotle synthesized the diverse aspects of his theory into a coherent framework which applied his principles of physics, cosmology, and matter theory just as Descartes' Theory of the Earth in Part IV of the *Principles of Philosophy* applied the earlier physical and cosmological conclusions of Parts II and III. Aristotle thus portrayed the Earth as a functional entity in an immutable cosmos, where cyclical motions of terrestrial generation and corruption correspond to the permanent revolutions of the heavenly orbs as the expression of an intelligible natural order. The comprehensive coherence of his theory, with intimate relations between his cosmology and thinking about the Earth, is evident in his summary of the relations between the land and the sea, as we have seen.[41] Recurring debates within Theories of the Earth regarding the eternity of the world were due in part to the prominence of Aristotle's *Meteorology* in the textual tradition.[42]

[39] René Descartes, "Les Meteores," in *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery, Vol. VI *Discours de la Methode & Essais* (Paris: Librairie Philosophique J. Vrin, 1965), 229–366. Descartes boasted of the absence of citations to Aristotle (see footnote 386 on page 621), so it is no surprise that he did not call attention to this correspondence in the sequential ordering of topics.

[40] Descartes and later Theorists drew extensively upon Aristotle's views (both pro and con), using his text as the implicit point of departure on many matters. See the list of key passages in the *Meteorology* already discussed with reference to Bourguet's taxonomy in "Aristotelian Theories of the Earth," beginning on page 188.

[41] See page 189ff.

[42] For the significance in Theories of the Earth of debates over the eternity of the world see Kubrin, "Providence and the Mechanical Philosophy."

§ 3-ii. Was Pre-Cartesian theorizing Essentially Cosmological?

Despite the parallels of topics between the *Meteorology* and Theories of the Earth, and despite Aristotle's systematic approach and attempt to achieve a comprehensive coherence, that Aristotle might have articulated a theory of the Earth is usually contested. As we have seen, Roger denied the possibility of pre-Copernican theories of the Earth, as if they were somehow inconceivable prior to the conceptualization of the Earth as a planetary body bearing no necessary ties to the cosmos as a whole. That Descartes invented Theories of the Earth in an entirely novel form distinct from all previous theorizing (which had been essentially cosmological) is asserted on the basis of arguments that earlier meteorologies and thinking about the Earth investigated the Earth not for its own character but only as a branch of cosmology or as a cosmic region, and that the idea of an interesting past for the Earth was literally inconceivable within pre-Cartesian hierarchical and non-directionalist cosmologies. We now respond to several forms of these arguments.

§ 3-ii-a. Critical Use of Non-Cosmological Evidence

Because modern historians persist in regarding pre-Cartesian theories of the Earth as mere exercises in cosmology—and therefore qualitatively different from seventeenth-century Theories of the Earth—it is important to note that Aristotle's conclusions followed a review of empirical evidence for changing shorelines over the previous centuries, which was hardly a cosmological issue and certainly bore no necessary relationship to Aristotle's geocentrism. Aristotle invoked cosmology to corroborate his inferences regarding the system of the Earth, but in the *Meteorology* he did not deduce his theory of the Earth *a priori* from his cosmological principles (though this is precisely what Descartes claimed to have accomplished).[43] Therefore it is untenable to claim that Descartes liberated the Theory of the Earth from cosmology while Aristotle did not, and it is no longer surprising that Descartes patterned his progression of topics in the *Principles of Philosophy* after the Aristotelian sequence. If there is coherence between an historical figure's cosmological theory and his theory of the Earth this does not imply an identity between the two, as if the theory of the Earth were practiced as only a component part of cosmology. Both Aristotle and Descartes achieved coherence between their cosmologies and their theories of the Earth, but both distinguished them as well.

§ 3-ii-b. Historical Continuity of the Meteorological Tradition

Another problem for Roger's post-Copernican prerequisite is the continuity of meteorological commentary with Theories of the Earth, including the Theory of Descartes. The obliging translator of Aristotle's *Meteorology* for the Loeb Classical Library suggested "That the *Meteorologica* is a little-read work is no doubt due to the intrinsic lack of interest of its contents."[44] However accurate this disarming claim may be as a characterization of twentieth-century readers, nevertheless it is false since historically the *Meteorology* was not a little-read work. Rather, there was sustained meteorological commentary through the seventeenth century in the tradition of Aristotle's *Meteorology* and Seneca's *Natural Questions*. Not only did Seneca cover many of the same topics as Aristotle, citing the *Meteorology* throughout, but he exclaimed, "If I had not been admitted to these studies it would not have been worth while to have been born."[45] Two hundred commentators in the middle ages apparently agreed with Seneca rather than the Loeb translator.[46] Renaissance meteorologies and astro-meteorologies

43 It might be objected that occasionally Aristotle did employ deductive arguments reasoning from cosmological premises to his theory of the Earth, as in this passage: "It is, then, generally agreed that the sea had a beginning if the universe as a whole had; for the two are supposed to have come into being at the same time. So, clearly, if the universe is eternal we must suppose that the sea is too." Aristotle, *Meteorology* II.III; 356b7–10; trans. Lee, 142–143. On the other hand, while such passages clarify and make explicit the coherence between cosmological systems and theorizing about the Earth, in the *Meteorology* empirical evidence plays a significant role quite unlike the *a priori* deductive structure of Descartes' *Principia*. See "Baptizing Descartes," beginning on page 602.

44 Aristotle, *Meteorology*; introduction by H.D.P. Lee, xxv.

45 Lucius Annaeus Seneca, *Naturales Quaestiones*, trans. Thomas H. Corcoran, vol. 1, 2 vols., Loeb Classical Library, no. 450 (Cambridge: Harvard University Press; London: Heinemann, 1971), I.4, pp.1 4-5.

continued to be widely popular through the seventeenth century.[47] Theorists of the Earth found meteorological topics of great interest and frequently cited the *Meteorology* and *Natural Questions*, situating themselves with respect to meteorological discourse as much as to Copernican or Cartesian cosmology—as suggested by Bourguet's category of Aristotelian Theories of the Earth.[48] Theorists from Kepler and Descartes to Deluc and Lamarck participated directly in meteorological commentary, often treating their own meteorological essays as Theories of the Earth or as adjuncts to their Theories of the Earth.[49] Seventeenth-century Theorists appropriated many topics which were investigated in meteorological treatises, including the water cycle and origin of springs, baths, spas, and caverns; vapors, exhalations, and winds; earthquakes and volcanos; the origin of figured stones or extraneous fossils; and even the invention and use of instruments such as barometers, thermometers, and hydrometers. The medieval and early-modern meteorological tradition is largely *terra incognita* for historians, but its mere existence makes extremely hazardous any claim that Descartes invented theories of the Earth in an entirely novel form.[50]

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[46] Two hundred medieval meteorological commentaries are included in Steven J. Livesey, *Commbase: An Electronic Database of Medieval Commentators on Aristotle and the Sentences* (http://www.ou.edu/class/med-sci/Commbase.htm, 1988–1999).

[47] Cf. the discussion of astrometeorologies in "Ptolemaic and Copernican sections of Leonard and Thomas Digges," beginning on page 411.

[48] See "Aristotelian Theories of the Earth," beginning on page 188.

[49] Examples are too numerous to list, but a typical seventeenth-century example is Thomas Robinson, *New Observations on the Natural History of this World of Matter, and this World of Life: In Two Parts. Being a Philosophical Discourse, grounded upon the Mosaic System of the Creation, and the Flood. To which are added Some Thoughts concerning Paradise, the Conflagration of the World, and a Treatise of Meteorology: With occasional Remarks upon some late Theories, Conferences, and Essays* (London: Printed for John Newton at the Three-Pigeons, 1696). One eighteenth-century example is François Para du Phanjas, *Theoria Entium Sensibilium, sive Physica Universa Speculativa, Experimentalis, Systemica et Geometrica, omnium captui accommodata*, 4 vols. (Venice: apud Laurentium Basilium, 1782–1783); volume 2 is entitled *Theoria telluris, aquae, et aeris*, while volume 3 covers *Theoria meteoricum*. An early nineteenth century example is Jean Baptiste Pierre Antoine de Monet de Lamarck, *Hydrogéologie ou Recherches sur l'influence qu'ont les eaux sur la surface du globe terrestre; sur les causes de l'existence du basin des mers, de son déplacement et de son transport successif sur les différens points de la surface de ce globe; enfin sur les changemens que les corps vivans exercent sur la nature et l'état de cette surface* (Paris: Chez l'Auteur; Agasse; Maillard, An 10, 1802). On pp. 187-188, Lamarck situated his work as being, like meteorology, a part of terrestrial physics; cf. Yves Delange, "Les phénomènes de l'atmosphère et la météorologie de Lamarck," in *Jean-Baptiste Lamarck, 1744-1829*, ed. Goulven Laurent (Paris: Editions CTHS, 1997), 123–136.

§ 3-ii-c. Were theories of the Earth Inconceivable in Pre-Copernican Cosmologies?

Roger argued that pre-Copernican cosmologies made the genre of the theory of the Earth entirely inconceivable.[51] Not only was pre-Copernican thinking about the Earth inseparable from cosmology, Roger argued, but given Aristotle's doctrine of natural place where the heaviest elements seek the center of the universe, in the Aristotelian conception the Earth was a region rather than a body. Only with Copernican cosmology when the Earth became regarded as a planet did it become possible to conceptualize the Earth as a body or object in its own right, the cognitive prerequisite for attributing to it the right to a particular formative past. This argument that the globe of solid earth was conceived solely as a region rather than a body with a potentially interesting history rests upon the recognition that according to both Plato and Aristotle, the Earth was a necessary part of the universe, without which the universe could not exist. Yet this view of the Earth as merely a necessary region of the cosmos was not an essential feature of pre-Copernican cosmology nor did it constitute an assumption so deeply engrained in habits of thought as to lie beyond the reach of critical challenge and sustained disagreement.

Although widely adopted, Roger's Bachelardian postulate of a Copernican discursive rupture fails on several counts.[52] Consider first that in defending the concept of a mobile Earth Copernicus himself relied on fourteenth-century arguments about the integrity of natural bodies resulting from the motion of the elements to their *relative* natural places in a cosmos containing multiple centers of attraction. Copernicus argued that the downward motion of earth and water and the upward motion of air and fire are not absolute with respect to the

[50] Cf. Stephen G. Brush, Helmut E. Landsberg and Martin Collins, *The History of Geophysics and Meteorology: An Annotated Bibliography*, Garland Reference Library of the Humanities, no. 421; Bibliographies of the History of Science and Technology, no. 7 (New York: Garland Publishing, 1985), Section M.

[51] Roger, "La Théorie de la Terre au XVIIe siècle," 26.

[52] Roger appears to follow Bachelard's disaffection with precursors and emphasis on conceptual discontinuity; cf. "Marginality, Incommensurable Mentalities, and Genres of Thought," beginning on page 346.

center of the universe, but may be relative with respect to the center of the body as a whole of which they are a part. For example, in the case of fire, "the motion of expansion is directed from the center to the circumference." Additionally, Copernicus explained that the clouds do not fall rapidly westward behind the eastward rotation of the Earth: "not merely the earth and the watery element joined with it have this motion, but also no small part of the air and whatever is linked in the same way to the earth."[53] Yet these arguments were not new with Copernicus, nor did they wait to become widely accepted until he penned them in the *De revolutionibus*. They were forcefully argued by fourteenth-century physicists such as Jean Buridan, William of Ockham and Nicole Oresme, for whom the Earth would still attract its surrounding elements even if it were not located in the center of the universe and even if it were in motion rotating around its axis or revolving around the Sun.[54] Aristotle's doctrine of earth's absolute natural place did not require a Copernican cosmology for its displacement.

Aristotle's meteorology is still rejected as a theory of the Earth because of his nondirectionalist cosmology. Gohau rightly points to the contrast between a nondirectionalist system and a directionalist geohistory as the key difference between the theories of Aristotle and Descartes:

> ... a hierarchical, finite universe had required maintenance of its structure and repair in case of degradation. Indeed, the Aristotelian earth maintained a dynamic stability through the action of partially interacting cycles. However, if the earth was a mere speck of dust in an infinite universe, its birth and origin became of interest, regardless of the fact that it may disappear or may not have existed forever: the earth had the right to a personal history. It is this history that Descartes started to narrate....[55]

[53] Nicolas Copernicus, *De revolutionibus*, I.8; *On the Revolutions*, trans. Edward Rosen, ed. Jerzy Dobrzycki, vol. 2 of *Complete Works*, 3 vols. (Baltimore: Johns Hopkins University Press, 1978), xx.

[54] Clagett translated excerpts from Buridan, Oresme and Copernicus with brief commentary in chapter 10 of Marshall Clagett, *The Science of Mechanics in the Middle Ages* (Madison: University of Wisconsin Press, 1959); on Ockham see Armand Maurer, "Ockham on the Possibility of a Better World," *Mediaeval Studies* 38 (1976): 291–312. For a general discussion see Pierre Duhem, *Cinquième Partie: La Physique Parisienne au XIVe Siècle (suite)*, vol. 9 of *Le Système du Monde: Histoire des Doctrines Cosmologiques de Platon a Copernic* (Paris: Hermann, 1958), 325–430; and Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994), chapter 20. Grant states (p. 639) that "Copernicus did not significantly add to the store of arguments proposed by his medieval predecessors."

Gohau's contrast vastly improves upon any suggestion that Descartes' thinking about the Earth transcended cosmology while Aristotle's did not, since here it seems to be a matter of *which* cosmological perspective rather than any that is at issue. However, the usual implication of such comments is that a hierarchical universe and a nondirectionalist cosmology rule out significant theorizing about the Earth. Yet the idea that the Earth had no "right to a personal history" in such a cosmology is an *a priori* supposition which is historically unwarranted. For example, Gohau's own textbook of the history of geology provides an accurate summary of the fourteenth-century theory of the Earth of Jean Buridan (described in the next section).[56] Moreover, Descartes' directionalist Theory of the Earth within a nonhierarchical cosmology was concerned more with specifying the causes of the formation of planetary "specks of dust" in general than with narrating the history of the Earth in particular. And for Descartes, the proper genetic account might very well turn out to be false as an actual specific history of the Earth.[57] On the other hand, Theorists as diverse as James Hutton and John Woodward held to nondirectionalist views of Earth, so Aristotle's theory cannot be regarded as beyond the pale solely on that account. In any case, the deployment of over-precise philosophical definitions of Theories of the Earth for the purpose of genre boundary-drawing serves no purpose given the prominence and persistence of eternity of the world controversies within the Theory of the Earth tradition, a fact which confirms the argument of Chapter 1 that the tradition consisted of a dialectic of debate on such issues rather than owing its character to any of the contending positions in isolation from the rest.[58]

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55 Gabriel Gohau, *A History of Geology*, trans. Albert V. Carozzi and Marguerite Carozzi (New Brunswick: Rutgers University Press, 1990), 41-42.

56 Gabriel Gohau, *A History of Geology*, trans. Albert V. Carozzi and Marguerite Carozzi (New Brunswick: Rutgers University Press, 1990), 27–30.

57 See footnote 375 on page 618.

58 This argument is made at greater length in Chapter 1; see "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22. Cf. Kubrin's acute analysis of the nondirectionalist views of Hakewell and Beaumont in the first chapter of "Providence and the Mechanical Philosophy."

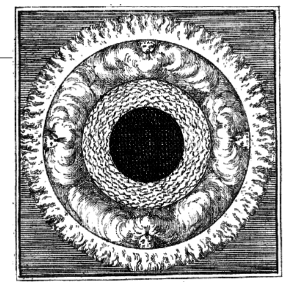

FIGURE 26. Thomas Burnet, *Doctrina Antiqua* title page detail. HSCI.

Description. A meteorological section showing the concentric bodies (*soma*) of earth, water, air, and fire as they would exist were it not for the constant mixing of the elements in the sublunar realm.

Even in the special case of Aristotle considered alone, an antithesis between the earth as a region and the Earth as a body does not quite hold up. Aristotle's emphasis in physical and cosmological treatises on the earth as a region did not exclude his conceptualization of the Earth as a body. In the *Meteorology* Aristotle noted that the four sublunar elements, although continually mixing together throughout the sublunar region, constitute four bodies: "The whole terrestrial region, then, is composed of these four bodies [σώματων]."[59] The main body of an amassed element is its natural place, the concentric region from which it is dispersed to mix with other elements; an Aristotelian section of four meteorological regions appears on an eighteenth-century title page next to the name of Thomas Burnet (Figure 26). For Aristotle, the corresponding main body (region, natural place or massing) might be obvious for three sublunar elements as the spheres of fire, air, and earth. Yet the case of water shows that it would be simplistic to take Aristotle's concentric stratification in a rigid, overly abstract sense. What should be regarded as the massed body of water? This question was subjected to extensive commentary not only in the meteorological tradition, but also in the hexameral tradition with respect to the "gathering of the waters" to form the body of the sea on the third day. In contrast to the model of four concentric sublunar elements, in the *Meteorology* Aristotle regarded the sea as the main body and natural place of water, and he treated the mingling of water and air together in a single sphere below the region of fire as constituting a joint province of water and air above a terraqueous globe.[60]

[59] Aristotle, *Meteorology* I.II; 339a20–21; trans. Lee, 6–7.

Indeed, it makes more sense to turn Roger's post-Copernican prerequisite on its head and argue that conceptualizing elemental regions around the Earth provided an occasion and stimulus for theorizing in meteorological discourse, since the meteorological regions were nothing if not places of constant change involving past configurations of the dry land and the sea and the origin of mountains (a case in point is section 4 of this chapter on the Earth's center of gravity). It would be a mistake to limit our attention to questions about the Earth as they were debated in commentaries on Aristotle's *De caelo,* or to conflate the meteorological discussions with pre-Copernican cosmology. As we shall see in later chapters, Theorists of the Earth such as Thomas Burnet frequently invoked the sublunar meteorological regions as they developed their accounts of the Earth's development.

The widespread adoption of Roger's post-Copernican prerequisite for thinking about the Earth is reflected in the following typical comment introducing a special issue of *Earth Sciences History* devoted to cosmological topics in geology: "After Copernicus, the boundary between Earth and the Cosmos blurs. In the Aristotelian worldview, a definite line demarcated two separate realms: the terrestrial and celestial. Copernicus erased the line."[61] Of course, Roger's definition of the genre of Theories of the Earth as a post-Copernican escape from cosmology does have the merit of undermining later propaganda that the tradition was

60 Aristotle, *Meteorology* I.IX; 346b16-20; trans. Lee, 68–69: "Let us deal next with the region which lies second beneath the celestial [i.e., beneath the fiery region] and first above the earth. This region is the joint province of water and air, and of the various phenomena which accompany the formation of water above the earth." Several chapters later, Aristotle upheld the view that the source of water is this co-region of air and water to argue against Plato's view of a central watery Tartarus, yet he asserted that the natural place of water is the sea. Aristotle regarded the natural place of an element as a massed body as well as a region, and as the destination of an element as well as its source: "The reason that made our predecessors think that the sea is the primary and main body of water is that they thought it reasonable to suppose that what was true of the other elements must be true of water. For each of them there is one mass which is primary because of its volume, and from which come those parts of it which change and are mixed with the other elements: thus there is a mass of fire in the upper regions, of air in the region beneath that of fire, and a main body of earth round which it is obvious that the other two lie. Clearly, therefore, we must look for something analogous for water. But there is no obvious single mass of water, as there is of other elements, except the sea." Aristotle, *Meteorology* II.II; 354b5-12; trans. Lee, 130–133. "The place occupied by the sea is, as we say, the proper place of water, which is why all rivers and all water there is run into it: for water flows to the deepest place...." Aristotle, *Meteorology* II.II; 355b14-19; trans. Lee, 137. The hexameral tradition resolved some of these ambiguities by assigning different states to the second and third days of creation. Compare the depiction of the sublunar realm on the second day in terms of concentric elemental spheres (e.g., Figure 26 on page 231) with depictions of the Earth as a terraqueous world at the end of the third day (e.g., Figure 68 on page 410).

61 Gregory A. Good, "Ever Since Copernicus," *Earth Sciences History* 17 (1998): 77.

nothing but an outmoded cosmological endeavor unrelated to geology (see Chapter 3). Yet even when pre-Copernican cosmology considered the Earth in relation to the cosmos it did not always assimilate the Earth to cosmology; the cosmos might also be brought down to Earth. For example, many ancient natural philosophers from Presocratics such as Anaxagoras, Pythagoreans such as Philolaus of Kroton, atomists such as Democritus and Lucretius, to later thinkers such as Plutarch and Galen, among others, argued that the Moon was Earthlike and perhaps inhabited.[62] In the same way, views that the Earth's exhalations reach to the Moon or beyond were commonly advocated throughout antiquity, as by Ptolemy in *Tetrabiblos* (I.4) or by Pliny in *Natural History* (II.vi) who explained the dark lunar spots (*maculas*; the modern maria) as earthy mud carried upward with rising moisture.[63] Such views do not merely make Earth a cosmological object by tying the Earth and cosmos together (perhaps involving the belief that the moist exhalations nourish the stars), but to some degree they also bring the Moon and Sun down to the level of Earthlike objects by diminishing the celestial-terrestrial dichotomy. If it was possible to conceptualize the Moon as Earthlike before Copernican cos-

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[62] Anaxagoras of Klazomenai (mid-fifth century B.C.) knew of the meteorite that fell at Aegospotami in 467 BC, and regarded it as typical of consolidated celestial material. Later, Diogenes of Apollonia (late fifth century B.C.) made a pilgrimage to Aegospotami to observe the meteorite, and on the basis of the meteorite's pockmarked appearance advocated that the Moon was made of pumice. Socrates denied the charge of holding the views of Anaxagoras in the *Apology*, 26d. These and other beliefs regarding the Earthlike character of the Moon from the Presocratics through the Renaissance are recounted with insightful analysis by Scott L. Montgomery, *The Moon and the Western Imagination* (Tucson: University of Arizona Press, 1999). Nor may Aristotle himself be taken as the supreme counterexample which foreclosed discussion. It is possible to exaggerate the role of the celestial-sublunar dichotomy in Aristotle's cosmological works when one reads them in isolation from his so-called "biological" works—from which they should not be abstracted, according to recent scholarship as sampled, for example, in Allan Gotthelf and James G Lennox, *Philosophical Issues in Aristotle's Biology* (Cambridge: Cambridge University Press, 1987). To take the example of physical life-forms, Aristotle's arguments that the Moon is made of ether did not prevent him from suggesting that fiery animals live there (*Generation of Animals,* 761^{b}15-22) and, for the sake of argument, Aristotle's *The Movement of Animals* leaves open the possibility that the Moon might be inhabited by human-like forms (699^{b}19): "Now 'impossible' has several senses: for when we say it is impossible to see a sound and for us to see the men in the moon, we use two different senses of the word. The former is invisible of necessity; the latter, though of such a nature as to be visible, will not actually be seen." *Aristotle's De motu animalium: Text with Translation, Commentary, and Interpretive Essays,* trans. and ed. Martha Craven Nussbaum (Princeton: Princeton University Press, 1978), 32, with commentary on p. 314. Both Aristotle's views and those of his later commentators on these less abstracted works would reward further study.

[63] Pliny wrote that "the stars [*sidera*] are undoubtedly nourished by the moisture of the earth, since she [the Moon] is sometimes seen spotted in half her orb, clearly because she has not yet got sufficient strength to go on drinking—her spots [*maculas*] being merely dirt [*sordes*] from the earth taken up with the moisture;..." Pliny the Elder, *Natural History, Books I–II*, trans. H. Rackham, vol. 1, 10 vols., Loeb Classical Library, no. 330 (Cambridge: Harvard University Press; London: Heinemann, 1938–1949), 196–197.

mology held sway, then why must it have been impossible to conceptualize the Earth as a planet-like body?

Copernicus' proof in the first book of *De revolutionibus* (1543) that there was no watery hemisphere—a fact that was by then widely acknowledged as a discovery of seafaring voyages despite the medieval theories of the Earth which had envisioned one—hints that geographical discoveries in the age of exploration were probably more important for stimulating renewed debate on the Earth than was Copernicus' setting the Earth in motion.[64] Europeans who beheld the discoveries from circumnavigational voyages (including Copernicus himself) did not require Copernican geokineticism in order to see the Earth as an interesting object.

Nor was it necessary to abandon geocentrism in order to conceive of the Earth as an interesting body in its own right. Many geocentric cosmologies featured the Earth as an object of special study, just as did Aristotle. Astrological beliefs often emphasized effects upon the Earth as an object of inquiry in the context of astronomical and cosmological discourse. Alchemists viewed the Earth as the interesting result of chymical processes of separation and transformation. Neoscholastics continued late medieval discussions of the formation of the Earth and the displacement of land and sea into the seventeenth century. As diverse a group as William Gilbert, Tycho Brahe, Francis Bacon, Christoph Clavius, Athanasius Kircher, and Thomas Robinson regarded geocentric cosmologies as not just a transitional compromise, but as a viable and coherent solution to a number of vital physical, cosmological, philosophical, theological, and meteorological problems.

§ 3-iii. Significance of the Meteorological Tradition

What, then, in a nutshell was the significance of the meteorological tradition for Theories of the Earth? Of course, meteorological changes raised important questions related to agricul-

[64] This point is discussed further in footnote 79 on page 245.

ture, mining, and geography. Yet more importantly, in the meteorological tradition enduring debate was established regarding the two major questions of (1) the possible eternity of the world and (2) the degree of intelligibility of sublunar phenomena or the role of chance and contingency. These discussions were continuous with Theories of the Earth. Most generally, the meteorological tradition established a discourse for debate about the natural order of the Earth that provided resources for conceptualizing and investigating contingent phenomena of the Earth. Let us stipulate that the contingent is that which might have been otherwise, for the contingent is not merely that which is rare or unique.[65] The place of the Earth in the center of the Aristotelian universe was unique, but necessarily so, not contingently. In Aristotle's *Meteorology* the Earth was non-contingent; it was a rarity to be sure, but one which could not have been otherwise, a unique but essential component of the universe. The Earth's existence and location was a cosmological necessity, as Roger insists. Yet understanding the Earth was more than a branch of cosmology, for according to Aristotle the particular phenomena of the surface of the Earth were contingent in themselves as the product of chance mixings only roughly reducible to general rules. It was noted above that Aristotle regarded the province of meteorology as "everything which happens naturally but with a regularity less than that of the primary element of material things...."[66] Ever-changing weather phenomena epitomize the contingency of the sublunar realm, which is not easily or readily reducible to regularities understandable through their natural causes. In contrast to Aristotle's modest epistemic aims in meteorology, Seneca insisted (consistent with his Stoic metaphysical commitments) that the sublunar realm was no less obedient to natural laws than the heavens, a position which much later would be echoed in Descartes' claims to certainty in the meteorological/Theory of the Earth sections of the *Principia*.[67]

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[65] Cf. the usage of "contingency" in the quotation of Gould on page 6 and the definition given in footnote 1 on page 7.

[66] Aristotle, *Meteorology* I.II; 339a20–21; trans. Lee, 5.

[67] See the discussion on page 620 ff.

Aristotle's *Meteorology* in itself constitutes a theory of the Earth by any conceptual criteria that are sufficiently broad to include nondirectionalist Theories of the Earth. Roger's strict post-Copernican contextual prerequisite fails, and with it any metaphysical explanation for the necessary emergence of Theories of the Earth only in the seventeenth century. Continuities with the Aristotelian meteorological tradition confirm that demarcation attempts are inherently problematic and were at times even constitutive of the tradition, and that textual, social, or historical criteria are preferable to strictly cognitive or conceptual definitions for delineating an early modern tradition. The systems of Plato and Aristotle, of Stoics such as Seneca, of Epicureans such as Lucretius, and of medieval and renaissance geographers who debated the figure of the Earth cannot be excluded from the category of theories of the Earth by any essentialist or universal conceptual criteria. The historical development of Theories of the Earth was a contingent rather than logically necessary process.

§ 4. Case 2: Earth's Center of Gravity

In the epigraph to Part I, Scott Montgomery suggests that global views are not geological. Neither are they merely cosmological; rather, Theories of the Earth were something else unto themselves. In this section one topic, *i.e.*, the center of gravity of the Earth, will illustrate the overlap of specific topics addressed in Theories of the Earth with cosmological traditions while simultaneously illustrating how mistaken it would be to conflate the invocation of such cosmological considerations with the enterprise of cosmology itself. For the Earth's center of gravity was a topic which travelled widely across disciplinary boundaries in cosmology, meteorology, hexameral commentary, geology and geophysics.

§ 4-i. Shifting Centers in early Theories of the Earth

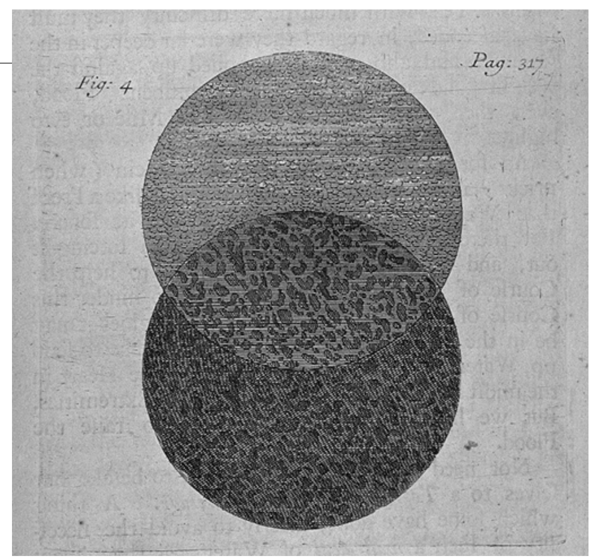

FIGURE 27. Erasmus Warren, *Fig. 4, Geologia* (1690), p. 317.

Caption. "....that Hypothesis which makes this Globe of ours *bi-central*: giving one Center to the *Earth* and another to the *Waters* in it; according to this Figure."

Explanation. Depiction of the distinction between the Earth's center of gravity (as the center of the sphere of water) and the Earth's center of magnitude (as the center of the bulk of the solid Earth).[68]

In *Geologia* (1690), Erasmus Warren canvassed six alternative mechanisms to his own Theory for supplying the waters of a universal Deluge. The fifth of these rejected options postulated that the Earth's center of gravity does not coincide with the center of the Earth's

[68] Warren's Figure 27 grossly exaggerated the required distance between the different centers. All theorists since Aristotle were well aware of the round shadow cast by the terraqueous globe during lunar eclipses, and many wrote of the fusion of earth and water into one habitable world—though few did so as eloquently as Cicero in *De natura deorum*, Book II.XXXIX.

magnitude (or volume), resulting in a sphere of water around the center of gravity that is distinct from the sphere of dry earth around the center of magnitude (Figure 27). In other words, the bulk of earth rises like bread where it is exposed to the Sun. As a consequence (to change the metaphor), it may float like an Archimedean cork upon the water, emerging above the sea in the known world and producing a watery hemisphere on the far side.

Although not unchallenged, belief in a watery hemisphere was prevelant in ancient and medieval geography. Indeed, apart from this belief it is impossible to understand why so many scholars suspected that Columbus and his crew would succumb to malnutrition and starvation before completing their journey to Asia across the vast Atlantic.[69] Discussions of the watery hemisphere took place in the context of at least four options (not mutually exclusive) open to medieval meteorologists and hexameral commentators for explaining why land protrudes above the level of the sea:

- *Initially-Lumpy Earth*: The solid Earth was made irregular from all time (or from the third day), due to processes such as condensation, crystallization, deposition, or the formation of subterranean cavities. The primeval continents and mountains protrude above the level of the sea, although thereafter the land gradually has been eroding down to the level of the sea.
- *Subsequent Scooping*: Even if the Earth were initially homogenous and perfectly spherical, nevertheless on the third day ocean basins were scooped out, creating a deep depression in the surface into which the waters would gather. It was customary for visual representations to follow St. Basil's supposition that the initial separation of land and sea was caused by the direct finger of God (cf. Table 45 on page 383). Dante attributed it to the fall of Satan in the *Divine Comedy,* and to astrological causes in a physical disputation (of course, these two explanations were not mutually exclusive).[70] Robert Grosseteste invoked a natural cause consistent with his light cosmology.[71]
- *Oceans standing above the Land*: The waters gather together in a heap, piling up above the level of the land, held together by the preternatural hand of God (Basil, Columbus, Luther) or cohering together in natural providence (Seneca) to ensure a habitable land (and in the process, supplying the pressure required to raise water in subterranean passages to account for mountain springs).[72]

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[69] This fear, based upon an accurate grasp of the size of the Earth (which Columbus denied) rather than belief in a flat Earth, prompted the opposition to Columbus' voyage. Cf. Jeffrey Burton Russell, *Inventing the Flat Earth: Columbus and Modern Historians* (New York: Praeger, 1991).

- *Rising Land*: The above metaphor comparing exposed dry land to rising bread is not completely far-fetched; in the thirteenth century it was sometimes supposed that if God once pushed back the waters to uncover any small portion of the land on the third day of creation, then thus exposed to the Sun, the earth would thereafter continue to expand, forming subterraneous caverns like air pockets in baking dough.[73]

Of course, subterraneous cavities were compatible with all of the above views (especially the first and the last), with or without a concomitant crustal collapse of the Platonic type to form an Atlantic Ocean spanning the western hemisphere. The first two options presume a relatively young Earth subject to destruction by erosion, and were more typical of directionalist

[70] The key passage in the *Inferno* is Canto XXXIV, lines 121–126; cf. Dante Alighieri, *Hell*, trans. Dorothy L. Sayers (New York: Penguin, 1949), 288. The disputation is available in Latin with facing Italian translation in Dante Alighieri, "La Questione de Aqua et Terra," in *La Vita Nuova di Dante Alighieri I Trattati De Vulgari Eloquio, De Monarchia E La Questione de Aqua et Terra*, ed. Pietro Fraticelli, Ottava Edizione (Firenze: G. Barbera, 1906), 416–451. Two English translations are Alain Campbell White, "A Translation of the *Quaestio de aqua et terra*, and a Discussion of its Authenticity," *Annual Report of the Dante Society* 21 (1903): 1–64; and A. G. Ferrers Howell and Philip H. Wicksteed, trans., *A Translation of the Latin Works of Dante Alighieri: The De vulgari eloquentia, De monarchia, Epistles, and Eclogues, and the Quaestio de aqua et terra* (London: J. M. Dent and Sons, Ltd., 1934). In an excellent accessible summary of Dante's cosmology Cornish notes (p. 208): "This primordial catastrophe precipitated the moral drama of the human race and at the same time formed the physical stage on which it was to unfold"; Alison Cornish, "Dante's Moral Cosmology," in *Cosmology: Historical, Literary, Philosophical, Religious, and Scientific Perspectives*, ed. Norriss S. Hetherington (New York: Garland, 1993), 201–216. That the cosmologies of the *Inferno* and the *Quaestio* are not contradictory is ably argued by J. Freccero, "Satan's Fall and the *Quaestio de aqua et terra*," *Italica* 38 (1961): 99–115. Important studies of Dante's cosmology include M. A. Orr, *Dante and the Early Astronomers* (1913; reprinted Port Washington, N. Y.: Kennikat Press, 1969); Edward Moore, "The Genuineness of the *Quaestio de aqua et terra*," in *Studies in Dante; Second Series: Miscellaneous Essays* (Oxford: Clarendon Press, 1899), 303–374; L. Oscar Kuhns, *The Treatment of Nature in Dante's Divina Commedia* (1897; reprinted Port Washington, N.Y.: Kennikat Press, 1971). Dante's interest in mineralogy has been investigated by Robert M. Durling and Ronald L. Martinez, *Time and the Crystal: Studies in Dante's "Rime Petrose"*, Centennial Book Series (Berkeley: University of California Press, 1990).

[71] "Once the heaven was made and the light was directed to the centre of heaven (i.e. the centre of the world and the centre of the earth) it may be that the impression of the light put into the waters (whether they were water specifically or only materially) a power that gave them a tendency to gather together; and maybe, once the water was removed, it put into the earth a power that gave it a tendency to germinate." Robert Grosseteste, *On the Six Days of Creation*, Auctores Britannici Medii Aevi, no. VI(2) (Published for the British Academy, Oxford: Oxford University Press, 1996), 124.

[72] Because Columbus believed that at one point he was sailing uphill, "ascending toward the heavens," he concluded that the figure of the Earth is not spherical but shaped like a pear, with the water piled up in a heap around the ancient antipodal location of paradise "as if it had a woman's nipple put there." Felipe Fernández-Armesto, *Columbus* (Oxford: Oxford University Press, 1992), 130–131.

[73] Jean Buridan summarized this view as follows: "And there is a conception that in the uncovered part the earth is altered by air and the sun's heat, and much air is mixed with it, so that this earth becomes rarer and lighter and has many pores filled with air or subtle bodies. However, the part of the earth covered with waters is not altered by air and sun and therefore remains denser and heavier. And therefore, if the earth were divided through the middle [center] of its magnitude [volume], one part would be much heavier than another, but that part which is uncovered would be much lighter. It seems, then, that there is one center of magnitude [volume] of the earth and another center of gravity.... its center of gravity is in the middle of the universe and not its center of magnitude. It is because of this that the earth is raised above the water on one side and is wholly under water on the other side." Edward Grant, trans. and ed., *A Source Book in Medieval Science* (Cambridge: Harvard University Press, 1974), 623.

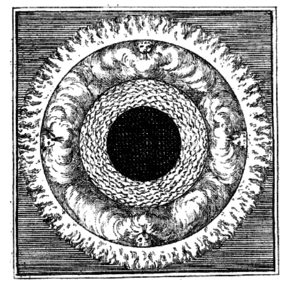
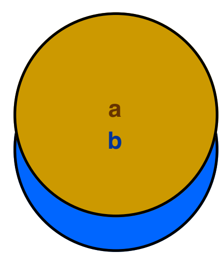
sensibilities of an Earth in decay. The latter two, which allow a perpetual habitation upon dry land, were more consistent with cyclic or steady-state views. All views were discussed in both hexameral commentaries and meteorological literature. Some hexameral accounts explained how a singular event in the creation week established a perpetually inhabitable globe as an enduring natural order. Others interpreted the days as disclosing the order of nature without implying temporal succession, and treated the events as suppositions or aids in abstract reasoning, an approach that was more consistent with Aristotle's eternalist meteorology.

In the fourteenth century an Archimedean twist was added to the last option, that of the rising land. Considering effects of shifting a center of gravity was a central problem addressed in the mechanics of Archimedes, whose works were translated by William Moerbeke in 1269. The idea was applied to the Earth as a large body by the fourteenth-century Parisian philosophers Jean Buridan and Nicole Oresme. Such Archimedean theories of the Earth, summarized in Table 28, emphasized the renewability of the dry land and allowed for a perpetually-habitable globe.[74] Neither Buridan nor Oresme attributed temporal reality to an initial watery state or to the hexameral days; indeed, neither were theologians, and neither explicitly invoked hexameral commentary in their discussions. Both were working in the meteorological tradition: Buridan gave his fullest exposition in his commentary on Aristotle's meteorol-

[74] See Ernest A. Moody, "John Buridan on the Habitability of the Earth," *Speculum* 16 (1941): 415–425, reprinted in *Studies in Medieval Philosophy, Science, and Logic: Collected Papers 1933–1969* (Berkeley: University of California Press, 1975), 111–125, and Nicole Oresme, *Le Livre du Ciel et du Monde*, trans. Albert D. Menut, ed. Albert D. Menut and Alexander J. Denomy (Madison: University of Wisconsin Press, 1968). The most comprehensive discussions of Archimedean theories of the Earth are Pierre Duhem, *Cinquième Partie: La Physique Parisienne au XIVe Siècle (suite)*, vol. 9 of *Le Système du Monde: Histoire des Doctrines Cosmologiques de Platon a Copernic* (Paris: Hermann, 1958), especially 293–308; and Edward Grant, "In Defense of the Earth's Centrality and Immobility: Scholastic Reaction to Copernicanism in the Seventeenth Century," *Transactions of the American Philosophical Society* 74 (1984): 1–69. The latter is summarized in Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994), chapter 20. Duhem characterizes Oresme as a critic of Buridan, but for the present purpose of exemplifying general features of Archimedean theories of the Earth their views may be treated in a composite manner as in Table 28 without concern for their differences. Translated excerpts from Buridan are provided in Marshall Clagett, *The Science of Mechanics in the Middle Ages* (Madison: University of Wisconsin Press, 1959), 594–599; and Edward Grant, trans. and ed., *A Source Book in Medieval Science* (Cambridge: Harvard University Press, 1974), 621–624. In Table 28 Oresme quotations are from *Le Livre du Ciel et du Monde*, and Buridan quotations are from Clagett or Grant, *Sourcebook*; in all quotations slight emendations have been made, particularly the substitution of "universe" for "world" in the translation of "monde" and "mundus."

ogy,[75] and Buridan regarded the Earth's duration as potentially eternal for the sake of philosophical investigation.

TABLE 28. Fourteenth-Century Archimedean Theories of the Earth: Jean Buridan and Nicole Oresme[a]

Main Point/Description	Quotation/Diagram
Initial conditions: Described in terms of the Archimedean concept of centers of gravity and magnitude. The Neptunist state (before the third day in hexameral accounts; a nonexistent mental abstraction according to Aristotelian meteorological theories) is shown in Figure 26 on page 231, reproduced here.	"if the earth weighed the same in all its parts, the center of its mass and the center of its weight would be identical—a single point—and this point would be the center of the universe. Then no part of its surface could be lower than another, and it would follow that the earth would be completely covered with water, save, perhaps, for the jutting peak of some mountains." (Oresme, 569) 
Question of Purpose: The initial conditions are contrary to the purpose of the globe, which is habitability. How, then, is that end maintained throughout all time despite erosion?	"God and nature have ordained that the earth should be thus exposed so that men and animals can live there;... the rest or remainder is enveloped by water and clothed or covered by the sea as with a hood or cap: The deep, like a garment, is its clothing." (Oresme, 569)
Two hemispheres: The solid earth (top) and watery hemisphere (bottom) do not coincide because the solid earth is heterogenous (containing cavities, metals, rocks of differing hardness, etc.) rather than of uniform composition. As a consequence it is possible to distinguish two different centers: **a** = center of the magnitude (quantité) or volume of the earth. **b** = center of the universe (monde), center of the earth's weight (pesanteur), center of the sea.	"And the center of the magnitude or volume of the earth corresponds to **a**, and the center of its weight is lower down at the center of the universe or at **b**, as can be imagined from the diagram. The surface of the sea is concentric with the universe and the centers of the sea and the universe are identical." (Oresme, 569) 

[75] Jean Buridan, *Questiones super tres primos libros metheororum et super majorem partem quarti a magistro Jo. Buridam. Queritur consequenter 20° de permutatione marium ad aridam et econverso* (Bibliothèque Nationale, fonds Latin, ms no. 14.723), as cited by Duhem who provides French translations of excerpts.

TABLE 28. Fourteenth-Century Archimedean Theories of the Earth: Jean Buridan and Nicole Oresme[a]

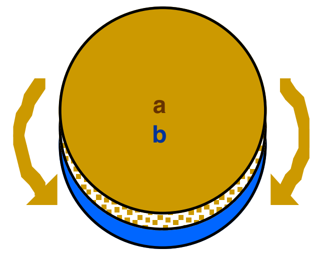
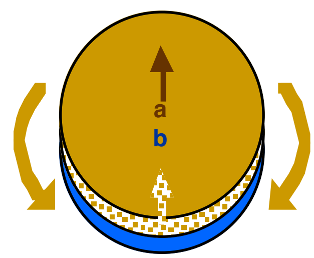
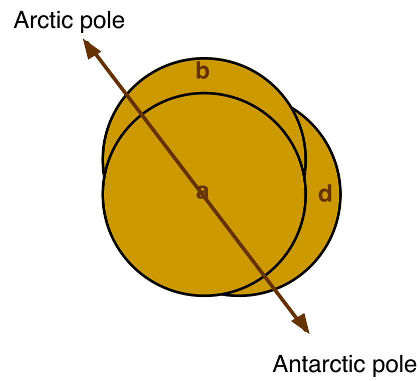
Main Point/Description	Quotation/Diagram
Mechanism for Maintaining Habitable Dry Land: Jean Buridan argued that the earth is constantly displaced in a cycle of erosion, marine deposition, and elevation. Debris eroded from the continents (which makes the sea salty) becomes deposited and coagulated into stratified, fossiliferous layers on the bottom of the ocean (right).	**Erosion and Marine deposition**  "By this another doubt is solved, evidently, whether the earth is sometimes moved according to its whole in a straight line. We can answer in the affirmative because from this higher part of the earth many parts of the earth (i.e., debris) continually flow along with the rivers to the bottom of the sea, and thus the earth is augmented in the covered part and is diminished in the uncovered part." (Buridan, in Clagett, 597–598)
As time passes, the redistribution of eroded debris is significant enough to alter the position of the dry land. The earth moves upward in a straight line with respect to the center of the universe, and newly-deposited strata move closer to the center of gravity (as shown in the speckled arrow, right). For the same reason, the rock previously located at **b** ascends toward **a**, and the rock previously located at **a** ascends toward the surface of the dry hemisphere. As various Archimedean theorists noted, variations on this process have the potential to explain earthquakes, the generation and destruction of mountains, and given an indefinite passing of time, the presence of marine fossils in strata on the tops of mountains.	**Elevation due to Shifting of Center of Gravity**  "Consequently, the center of gravity does not remain the same as it was before. Now, therefore, with the center of gravity changed, that which has newly become the center of gravity is moved so that it will coincide with the center of the universe, and that point which was the center of gravity before ascends and recedes, and thus the whole earth is elevated toward the uncovered part so that the center of gravity might always become the center of the universe." (Buridan, in Clagett, 597–598) "The generation of the highest mountains is thus also saved, because there are very dissimilar parts within the earth—as diggings show…." (Buridan, Grant, 623)

TABLE 28. Fourteenth-Century Archimedean Theories of the Earth: Jean Buridan and Nicole Oresme[a]

Main Point/Description	Quotation/Diagram
Mechanism for the Deluge: In addition to the phenomena noted above, this theory provides a mechanism to explain the Deluge. To return the Earth to the watery state nothing more is required than to make the centers of gravity and magnitude once again coincide, like bobbing a cork under water (cf. initial conditions, first row above).	"From what has been said, it can be inferred that, if God and nature caused the habitable portion of the earth to become as heavy as the other or caused the weight of the other part to diminish so that the whole earth were uniform in weight in all its parts, then the habitable portion would be lowered and the whole earth would be plunged into the sea and covered with water, just as a man covers his face with his hood. Thus, there could be a universal deluge without rain." (Oresme, 569–570)
Mechanism for Displacement of land and sea; Polar wandering: This theory did not require that the dry land and watery hemisphere always remain in the same orientation. Consistent with a theory of the Earth "according to Aristotle" the relative position of land and sea may be displaced after thousands of years. Oresme supposed that elemental transformations between earth and water might shift the relative bulk of the earth and cause the surface of the earth to change position with respect to the poles. He noted that polar wandering would cause the sun and stars as seen from point **b** to rise in the west and set in the east, and he cited traditions which alleged that such a change had actually happened more than once during Egyptian civilization. (Oresme, 573, 97.)	"Therefore, assuming some notable addition to be made by generation in some part of our earth, such as, for example, the part in which we live... which part is indicated as **b**... I say that... according to Aristotle... the  place **b** where we are would descend toward the center of the universe called **a**, as can be imagined from the diagram. Next, I imagine that a similar addition was made to the earth towards the south at the place marked **d**, which is distant from **b** by one-quarter of the earth's circumference; I say that in this way **d** would be drawn toward the center of the universe and that, consequently, **b** would be drawn farther toward the left. It is clear that, as a result, that **b**, where we are, would move toward the arctic pole.... Let us assume, as is possible, that this elevation of the pole amounted to one degree and that much later, in the same manner, the pole were raised another degree, and then another, and another, and so on; I say that this process could go on naturally for thousands and thousands of years until **b**, where we are, would have traveled half-way around the circumference and would be positioned with respect to the antarctic pole just as we are to the arctic pole and that the antarctic pole would be above **b** the same number of degrees that the arctic pole now is. This being so... I say that the sun and stars at **b** would rise from the part we call west and would set in the opposite direction." (Oresme, 571)

a. Sources for quotations are given in footnote 74 on page 240.

By distinguishing the center of magnitude of the Earth from the center of the universe, the Archimedean theories "freed the earth from the weight of the cosmos" as natural philosophers considered the Earth as possessing an interesting formative past before the advent of Copernican cosmology.[76] Fourteenth-century contemporaries such as Henry of Langenstein (d. 1397) and Paul of Burgos (ca 1350–1435) adopted the Parisian mode of analysis, holding that God supernaturally lowered the watery sphere's center of gravity on the third day.[77] Duhem showed that philosophers responded favorably to Buridan's theory of the Earth in a long line from Albert of Saxony, John Major, Themon Judaeus, Marsilius of Inghen and Pierre D'Ailly to Leonardo da Vinci.[78] Of course, all appropriations involved transformations and revisions, such as disputes about whether the Earth is moved with small rectilinear motions. The discovery of the New World occupying the middle of the supposedly watery hemisphere (with few signs of Eden or Purgatory) required revisions to the theory. After the geographical discoveries of Columbus and the Portugese explorations of Brazil in 1501, many reverted to the idea of a lumpy Earth such as Joachim Vadianus (1481–1551) of Switzerland, who wrote to the humanist educator and dialectician Rudolf Agricola (1443/4-1485) that the earth and water form a single globe with a single center, with the earth partly submerged and partly elevated.[79] However, Archimedean theories were not wedded to belief in a watery hemisphere and outlived the discovery of the New World in part by explaining an Aristotelian displacement of the land and sea as due to oscillating fluctuations around the Earth's center of gravity rather than a continuous motion in a straight line. As Duhem pointed out, Archimedean theories remained a live option well into the seventeenth-century, particularly in scholastic circles. They were discussed in textbooks such as the *Sphaera* (1629) of Jacques du Chevreul (ca. 1593–1649), a scholastic who taught physics and mathematics at Paris.[80] They were

[76] See Roger's quotation on page 207.

[77] Grant, *Planets, Stars and Orbs*, 632. Nicholas H. Steneck, *Science and Creation in the Middle Ages* (Notre Dame, 1976), 80.

[78] Duhem, *Le Système du Monde,* especially 309–323. Cf. Grant, *Planets, Stars and Orbs*, 624–625.

endorsed by a variety of Jesuits such as Gabriel Vazquez (1551–1604), Paul Guldin (1577–1643), and Niccolo Cabei de Ferrare (1629).[81]

Although Warren gave such views only cursory attention, other Theorists such as Steno alluded with greater respect to seventeenth-century versions of the theory that the Earth's center of magnitude and center of gravity might not coincide:

> Regarding the manner in which the waters rose, we can put forward various agreements with the laws of nature. If it should be said that the center of gravity of the Earth does not always coincide with the center of its figure, but sometimes moves away from one side, sometimes from the other, according to the formation of subterranean cavities in different places, it is possible to put forward a ready reason

[79] Grant, *Planets, Stars and Orbs*, 635. Rudolf Agricola is not to be confused with Georg Bauer or Georgius Agricola (ca. 1494-1555), author of *De re metallica* (1556). Grant's statement that the idea of a terraqueous globe was a late development in seventeenth-century scholasticism (Grant, *Planets, Stars and Orbs*, 635) is misleadingly precise, for such a claim refers specifically to the position articulated by Albert of Saxony and endorsed by Pierre D'Ailly that the Earth's center of gravity at the center of the universe is the center neither of elemental earth nor of elemental water but of the aggregate of earth and water, which was followed by the post-Columbus argument of Copernicus and Clavius that earth and water share a common center of gravity. However, a similar position was also held by those who adopted the "lumpy Earth" option described above. Hexameral and meteorological "lumpy Earthers" and writers such as Cicero (footnote 68 on page 237) suggest that Goldstein exaggerates the novelty of the "Renaissance concept of the Earth" which he describes as "the new realistic concept of the earth—which in scientific terms meant the globe as a solid, three-dimensional body with a diversified surface, made up of varied portions of land and sea," which was an "authentic Renaissance creation" deriving primarily from geographic discoveries; Thomas Goldstein, "The Renaissance Concept of the Earth and its Influence upon Copernicus," *Terrae Incognitae* 4 (1972): 20–21. Goldstein goes even further than Grant in pressing the case for a Rogerian-style Copernican discursive rupture when he claims that "the new globe was *first identified as an integral body* by a group of amateur geographers working in Florence during the early fifteenth century, who may or may not have realized how much their *new idea of the human habitat* undermined the Aristotelian teachings, which invariably divided the earth into the two separate spheres of the elements 'earth' and 'water.' It was confirmed in empirical terms by the actual voyages of exploration, in particular the discovery of the New World. It was accepted by Copernicus as a decisive piece of evidence, both for his astronomical theory about the dual motion of the earth and for his remarkable anticipation of the early modern physical universe, through which he in effect replaced the Aristotelian system of physics and established the outlines, in however a sketchy form, for the more explicit physical laws of early modern science." Goldstein, 21; italics added. On page 231 I have argued that the description of Aristotle's concentric elemental spheres is a caricature of his position on the natural place of water, and in the manner of Cicero the meteorological and hexameral traditions had long treated the terraqueous globe as a single integral body. Archimedean distinctions between the center of gravity and the center of magnitude of the body of elemental earth assumed rather than negated this general sense of the Earth's integrity as a habitat for life with an interesting formative past.

[80] Jacques Du Chevreul, *Sphaera Iacobi Capreoli* (Lvtetiae: Apud Hervetvm dv Mesnil, 1629), 50ff.

[81] Duhem, 293–323. Among the Jesuit works cited by Duhem are Niccolo Cabei de Ferrare, *Philosophia magnetica* (Ferrariae: Apud Franciscum Succium superiorum permissu, 1629); and Paul Guldin, "Dissertation Physico-Mathématique du Mouvement de la Terre," in *Centrobaryca* (Viennae Austriae: Formis Gregorii Gelbhaar Typographi Caesarei, 1635). Grant documents that after the condemnation of Copernicus in 1616, most scholastic authors (like Raphael Aversa) denied the motion of the Earth in favor of theories which kept the center of gravity in equilibrium without requiring small, abrubt readjustments; for this reason Guldin retracted his previous views. Pierre D'Ailly had earlier argued that the parts of the earth move but the solid earth as a whole does not, just as a pile of stones might remain in the same position despite the changing position of the stones themselves. Grant, *Planets, Stars and Orbs*, 625–626.

> why the fluid that covered everything in the beginning of things left certain places dry, and returned again to occupy them.[82]

Following Steno, Leibniz also considered the possibility of the displacement of the Earth's center of gravity from its center of magnitude.[83] However, like Warren, Steno preferred different, more directionalist alternatives:

> The universal deluge may be explained with the same ease if a sphere of waters, or at least huge reservoirs of water, are arranged around the fire in the middle of the Earth; whence, without movement of the centre, the outpouring of the enclosed waters could be derived, but the following method also seems quite easy to me; by which both a lesser depth of valleys and a sufficient quantity of water are obtained without considering the center, either of the figure or of gravity.[84]

Again following Steno in articulating a directionalist system, Leibniz preferred the supposition of subterranean reservoirs from which waters might pour forth. Noting that magnetic variation suggested the motion of a magnetic body within the Earth, perhaps associated with subterranean cavities, Leibniz supposed a subterranean reservoir of air in addition to water in order to propel a second outpouring at the time of the deluge.[85]

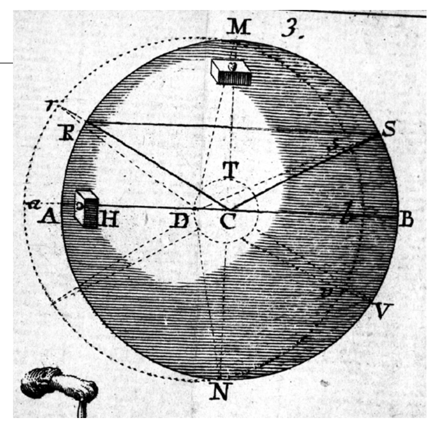


FIGURE 28. Para du Phanjas, *Theoria telluris* (1782), *Figure 3*.

Description. This figure illustrates how a displacement of the seas to the hemisphere *MAN* results from the shifting of the Earth's center of gravity from *C* to *D*. LH.

Archimedean theories of the Earth were seriously discussed through the seventeenth century, forming a

[82] Steno, *Prodromus,* in Nicolaus Steno, *Steno: Geological Papers*, trans. Alex J. Pollock, ed. Gustav Sherz (Odense: Odense University Press, 1969), 204–207; hereafter Steno, *Prodromus*.

[83] Gottfried Wilhelm Leibniz, *Protogaea: De l'aspect primitif de la terre et des traces d'une histoire très ancienne que renferment les monuments memes de la nature*, trans. Bertrand de Saint-Germain, ed. Jean-Marie Barrande, Latin text with facing French translation (Toulouse: Presses Universitaires de Mirail, 1993), Section VI, 28–29. Hereafter Leibniz, *Protogaea*.

[84] Steno, *Prodromus,* 204–207.

[85] Leibniz, *Protogaea*, 29.

locus that was continuous with considerations of the Earth's center of gravity in Theories of the Earth by Robert Hooke,[86] Lewis Evans (1755),[87] or Élie Bertrand (1766),[88] among others. For example, after reviewing the Theories of Whiston, Burnet, Woodward, Leibniz, and Buffon, François Para du Phanjas defended the proposition that in all probability the Earth's center of gravity has shifted (Figure 28).[89] A similar idea was proposed by Emmanuel

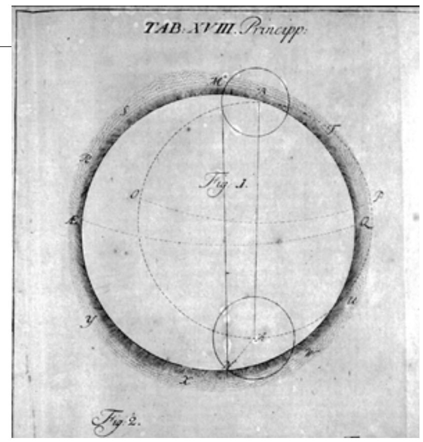


FIGURE 29. Swedenborg, *Principia rerum* (1734).

Swedenborg (Figure 29).[90] The topic of the Earth's center of gravity, of course, was just one locus among dozens, and it was just as often intertwined with other related topics such as the displacement of the land and the sea, the Earth's magnetic core, the figure of the Earth, changes in

[86] Cf. "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354.

[87] Lewis Evans, *A General Map of the Middle British Colonies, in America; Viz. Virginia, Màriland, Dèlaware, Pensilvania, New-Jersey, New-York, Connecticut, and Rhode Island* (Philadelphia: Published according to Act of Parliament by Lewis Evans, June 23, 1755, and sold by R. Dodsley, in Pall-Mall, London, & by the Author in Philadelphia, 1755); Lewis Evans, *Lewis Evans and His Historic Map of 1755: First Known Document to Show Oil at the Industry's Birthplace* (Color facsimile reprint with booklet; New York: Ethyl Corporation, 1953). Lewis Evans, *An Analysis of a General Map of the Middle British Colonies* (Philadelphia: Benjamin Franklin and D. Hall, 1955). George W. White, "Lewis Evans' Early American Notice of Isostacy," *Science* 114 (1951): 302–303; George W. White, "Lewis Evans' Contributions to Early American Geology, 1743–1755," *Illinois Academy of Science Transactions* 44 (1951): 152–158. Describing Evans in a way that places him squarely in the tradition of late medieval Archimedean theories, White suggests that such theories were conceptually akin to the idea of isostasy: "The term 'isostacy' was first proposed by Dutton in 1889. As early as about 1500 Leonardo da Vinci recognized that change of load causes movement of the earth's crust. The earliest recognition in America of what we now call isostatic adjustment appears to have been in 1743 by Lewis Evans, colonial surveyor, cartographer, and geological observer." White, *Science*, 302.

[88] "Il en est d'abord qui ont supposé que le centre de gravité n'étoit pas fixe, mais mobile, et qu'il se mouvoit effectivement d'un mouvement très lent, en s'approchant successivement et uniformément de tous les points de la surface du Globe." Élie Bertrand, *Recueil de Divers Traités sur l'Histoire Naturelle de la Terre et des Fossiles* (Avignon: Chez Louis Chambeau, Imprimeur-Libraire, 1766), 43. As an advocate of this theory, Bertrand cited François Bernier (1620–1688). Ellenberger lists a number of other theorists who debated various Archimedean theories; François Ellenberger, *La Grande Éclosion et ses Prémices, 1660–1810*, vol. 2 of *Histoire de la Geologie*, 2 vols., Petite Collection d'Histoire des Sciences (Paris: Technique et Documentation—Lavoisier, 1994), 25–28.

[89] François Para du Phanjas, *Theoria entium sensibilium, sive Physica universa speculativa, experimentalis, systemica et geometrica, omnium captui accommodata,* 4 vols. (Venice: apud Laurentium Basilium, 1782–1783), 41–44. This work, originally published in French, follows a scholastic mode of presentation. As a "universal phyiscs," it consists of four volumes, the second of which may be regarded as a Theory of the Earth: *Theoria materiae*; *Theoria telluris, aquae, et aeris*; *Theoria meteoricum, lucis, ignis, electricitas*; and *Theoria caeli, sive astronomia, geometrica, et physica*.

the inclination of the Earth's axis, or polar wandering. Admittedly, it is quite arbitrary to isolate this locus as a unit idea and to ignore a host of important contextual meanings, but the purpose of this discussion is not to provide an intellectual history of Theorists who discussed it. Although space does not permit even a brief account of this specific topic, the vignettes presented so far (along with two later Theorists—Louis Bertrand and Joseph Alphonse Adhémar, to follow) are sufficient to suggest that there were important continuities between Theories of the Earth and other traditions, both earlier and later.[91] Because of discipline-crossing boundary-objects like commonplace discussions of the Earth's center of gravity, it is inadequate to regard Theories of the Earth either as a direct consequence of Copernican cosmology or as an essentially cosmological enterprise in contrast to later geology and geophysics.

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90 Emanuel Swedenborg, *Principia Rerum Naturalium sive Novorum Tentaminum Phaenomena Mundi Elementaris Philosophice Explicandi*, vol. 1 of *Opera philosophica et mineralia* (Dresden, Leipzig: Sumptibus Friderici Hekelii, 1734).

91 Ariew uses two different topics (the origin and present location of fossils) to make the same point as the present discussion of center of gravity; cf. Roger Ariew, "A New Science of Geology in the Seventeenth Century?," in *Revolution and Continuity: Essays in the History and Philosophy of Early Modern Science*, ed. Peter Barker and Roger Ariew, Studies in Philosophy and the History of Philosophy, 24 (Washington, D.C.: Catholic University of America Press, 1991), 81–93. Ariew's brief article urges a partial continuity between seventeenth-century geology and certain scholastic positions. He examines the content of specific theories which, he urges, evolved piece-meal, without global paradigm change. While Ariew concedes a new science of geology in the seventeenth century, he denies that it sprang *de novo* from the brow of Descartes. In particular, Ariew examines two particular issues in order to show that seventeenth-century geology developed in partial continuity with scholastic discussions. The two issues are first, the formation of fossils and whether they are the transformed remains of once-living creatures; and second, how fossils or shells came to be located on the tops of mountains. On the first issue he concludes (p. 87) that "the seventeenth-century doctrines of Steno, Scilla, and Leibniz should be considered, in part, as a return toward the older theories of Avicenna and Albertus Magnus, that fossils are the remains of animals, but with a different, mechanistic account (as opposed to an account based upon some kind of virtue, force, or power) for the process of petrification." With respect to the second, Ariew concludes that Leibniz and Steno returned "to what was a standard doctrine before Buridan, of outlets or caverns in which the waters covering the mountains had receded. The doctrine was used generally to explain the formation of mountains and the mechanism for a natural deluge, at least as early as Avicenna."

§ 4-ii. Shifting Center of Gravity in a later Theory of the Earth: Louis Bertrand

In his survey of Theories of the Earth (Table 24 on page 199), Cuvier cited a book by Louis Bertrand on the periodic renewal of the terrestrial continents, published in Paris and Hamburg in 1799. Bertrand (1731–1812), a mathematical writer, was an emeritus professor of the Academy of Geneva and a member of the Academy of Sciences and Belles-Lettres in Berlin.[92] We may summarize his system with three main points:

- *Formation of Continents*: The present continents formed under the sea and were uncovered when the sea retired.
- *Inundation of Continents*: The sea retired due to a displacement of the Earth's center of gravity caused by the chance passing of a comet, which attracted a movable central body within the Earth. This movable central core, a magnetic body, was pulled from one pole to the other as it followed the passing comet.
- *Reciprocal Destruction and Renewal of Continents*: Ocean waters now cover the southern hemisphere, yet after an unknown number of centuries another comet will pass. The resulting concomitant movement of the core will shift the Earth's center of gravity again, and then the sea will cover the northern hemisphere instead.[93] In the past there has been a regular pattern of submersion varying with latitude, alternating north and south. Only the equator remains always at the same height above sea level, regardless of which pole is covered with water. Thus single inundations are not global in extent, but they successively cause changes on a global scale.

[92] Louis Bertrand, *Renouvellemens Périodiques des Continens Terrestres* (Paris: Chez Charles Pougens, imprimeur-libraire; Hocquart, libraire; Duprat, libraire, An 8, [1799]). The Hamburg edition is cited in Georges Cuvier, *Essay on the Theory of the Earth*, trans. Robert Kerr (Edinburgh: Printed for William Blackwood, Prince's Street; and Baldwin, Cradock, and Joy, Paternoster Row, London, 1817), 47. Cuvier cited Bertrand along with Delamétherie, Hutton, Lamanon, Dolomieu, and de Marschall to illustrate the diversity of incompatible Theories, thereby opening the way for the introduction of his own Theory based upon the superior evidence of comparative fossil anatomy and geognostic fieldwork (on Cuvier's Theory of the Earth see "Controversy and the Rhetoric of Demarcation," beginning on page 307). Cuvier's entire description of Bertrand is brief and accurate: "By a sixth [Theorist], the globe is supposed to be hollow, and to contain in its cavity a nucleus of loadstone, which is dragged from one pole of the earth to the other by the attraction of comets, changing the centre of gravity, and consequently hurrying the great body of the ocean along with it, so as alternately to drown the two hemispheres." A second edition of Bertrand's Theory appeared in 1803; Louis Bertrand, *Renouvellemens Périodiques des Continens Terrestres*, 2d ed. (Genéve: J. J. Paschoud, An XI, 1803). Bertrand also published mathematical and geometrical texts: Louis Bertrand, *Developpement Nouveau de la Partie Élémentaire des Mathématiques*, 2 vols. (Genève: Chez Isaac Bardin, 1778); and Louis Bertrand, *Élémens de Géométrie* (Paris et Genève: Chez J. J. Paschoud, 1812).

[93] "De cette manière, chaque alternative produiroit l'émersion de nouveaux continens et la submersion des anciens, et jamais la terre ne cesseroit d'offrir à ses habitans un séjour enrichi de tout ce qui est nécessaire à leur conservation et à leur bien-être." Louis Bertrand, *Renouvellemens,* 293–294.

An outline of the contents of Bertrand's text (Table 29) shows that in the first eight chapters preliminary geological facts and inferences are considered to establish the first point regarding the submarine formation of continents, in which Bertrand's system resembles Neptunist views. However, Bertrand rejected the usual Neptunist assumption of a diminishing primeval ocean, with its directionalist framework, in favor of a perspective of cyclical renewal.

TABLE 29. Louis Bertrand (1799) Outline

Ch.	Topic	Comment
1	Of the layers which envelope the Earth.	
2	Of the animal remains of all kinds and species found in the terrestrial layers.	
3	Refutation of diverse objections proposed against the true origin of shellfish and petrifactions.	
4	Of the transport of rolled pebbles	Refutation of the system of Leibniz on the causes which have prepared the actual state of the Earth.
5	Phenomena observed in the valley of Lake Geneva	That the correspondence of layers from mountain to mountain, or from shore to shore, does not prove that the mountains or the shores were once joined by an intermediary massif. That the boulders of alpine rocks distributed over the Alps have been carried to where they are now found by the force of water currents, and not by fire. That the sea did not retire from our continents gradually by degrees, but in one sudden and violent manner.
6	Continents formed beneath the sea	It follows from the present state of the Alps that the continents were formed under the sea and not from fire.
7	Formation of stalactites	
8	Refutation of the system of Deluc, that the continents are permanent and grow by accretion.	
9	The phenomena of the magnetic needle prove that the Earth is a hollow sphere, containing a void space in which a magnetic globe rotates and can move translationally.	
10	The means by which vegetation and animal life are preserved on the Earth	Discussion of Siberian elephants, and the cause by which the height of mountains is proportional to their latitude (with the highest near the equator, and declining toward the poles).

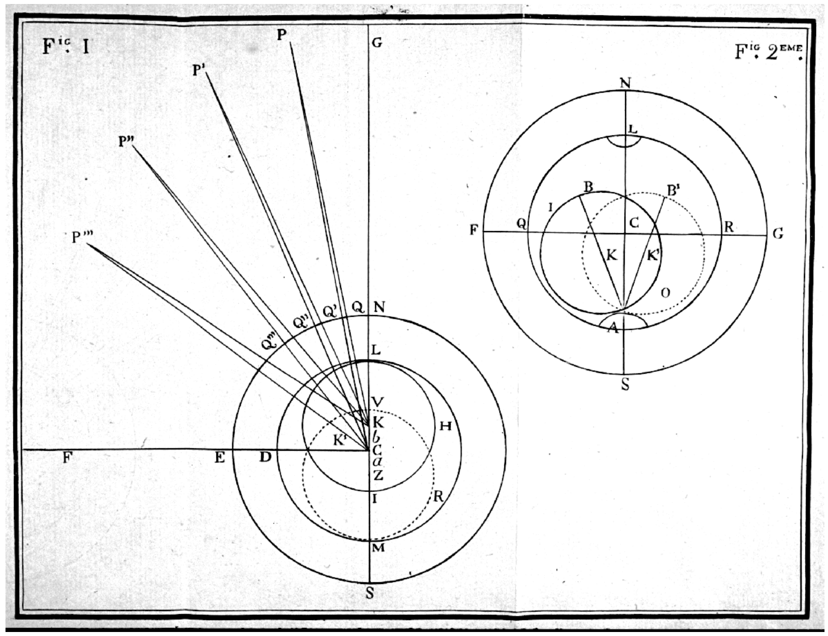

FIGURE 30. Louis Bertrand, *Figures 1 and 2*

TABLE 30. Key to Louis Bertrand's Figures 1 and 2

Area	Label	Description
Earth Axis	NS	North and South poles on the axis of the Earth
Outer shell	C	Center of the outer shell of the Earth
	NSE	Outer surface of the Earth
	MDL	Concave surface of the outer shell
Magnetic core	IHL, MRV	Inner magnetic core at T_I, T_F[a] (Fig. 1)
	K, K'	Center of the inner magnetic core at T_G, T_F[a]
	b, a	Earth's center of gravity at T_I, T_F (Fig. 1)[a]
	LCM	Axis of inner core (Fig. 1); line of translational movement
	AB, AB'	Axis of inner magnetic core (Fig. 2); secular variation
Comet	P, P'... F	Comet positions at T_I, T_F[a]

a. In the Table descriptions of Fig. 1, T_I and T_F (not Bertrand's terms) designate initial and final conditions before the approach of a comet and after it has receded.

In the ninth chapter Bertrand took up the phenomena of magnetism, which provided the observational basis for inferring the existence of the central movable body required for the second and third points of his Theory as summarized above. Following the Theory of "le grand Halley," the existence of the movable magnetic core was inferred from secular variations in the location of magnetic north.[94] As Bertrand illustrated in *Fig. 2^eme^* (Figure 30), *AB* is the axis of the magnetic core, which never quite touches the outer crust except perhaps at a base (*A*) near the pole. In roughly half a day, as the outer crust rotates around the Earth's axis *NS*, the inner core moves with it from *AB* to *AB'*. Compounding this diurnal motion, Bertrand supposed that the axis of the magnetic core rotates with its own period, perhaps at a rate equal to or near the precessional period of about 25,000 years, during which time the magnetic poles would slowly change their location with respect to the surface of the crust.[95]

By depicting one interior core body rotating on a single axis Bertrand rejected the argument of the American writer John Churchman that the Earth has two magnetic poles, each of which move independently with unequal periods and at any given time are located at different distances from the north or south pole respectively.[96] Rather, the existence of only one inner magnetic body, positioned eccentrically rather than concentrically (contra Halley), makes it possible to explain much more than the variation of magnetic poles, because the magnetic body can move translationally from pole to pole as well as by rotation. *Fig. I* (Figure 30) diagrams how the magnetism of a celestial body such as a passing comet might affect the Earth's magnetic core, by transferring it from one pole to the other.[97] If a comet approaches the Earth from the north (*G, P*) and moves around to F and beyond, finally passing by to the south, the comet will differentially attract the outer crust's center of gravity (*C*) and the mag-

[94] Halley's Theory is described in Chapter 6; see "Magnetic Theories of the Earth," beginning on page 631.

[95] Louis Bertrand, *Renouvellemens,* 292–293.

[96] Cf. John Churchman, *An Explanation of the Magnetic Atlas, or Variation Chart, Hereunto Annexed; Projected on a Plan Entirely New, by which the Magnetic Variation on any Part of the Globe may be Precisely Determined, for any Time, Past, Present, or Future: and the Variation and Latitude being Accurately Known, the Longitude is of Consequence Truly Determined* (Philadelphia, 1790), revised 1794, 1800.

netic center of the inner core (*K*), as shown by lines drawn from each position of the comet (*P*) to both *C* and *K*. (Compounding the outer crust and the inner core, the center of gravity of the Earth is *b*.) As the comet moves to the south, its attraction will cause the inner core to roll southward, its center moving to *K'* and eventually to *Z*, so that the core will come to occupy the position *MRV*. The net result is a change in the Earth's center of gravity from *b* to *a*. As a consequence of the displacement of the Earth's center of gravity, the oceans will move southward, becoming more elevated over the southern hemisphere than previously, covering southern lands previously exposed and exposing northern land previously submerged.[98] Finally, Bertrand argued that his theory was consistent with the calculations of "le grand géomètre de la Place."[99]

Kenneth L. Taylor's distinction between idiosyncratic and systemic cosmological considerations is quite helpful. Considerations of regular phenomena and constantly-acting causes, such as the oblate spheroidal figure of the Earth or the effects of solar heat, are described as *systemic*:

> One type of geological concern with extraterrestrial agents, which I shall refer to as *systemic*, concerns the outlook of scientific writers of wide perspective who presumed that a satisfactory comprehension of the Earth could not be complete without recognition of its existential condition as a planet, its constant and regular susceptibility to universal physical conditions....[100]

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97 "...on remarquera que, de quelque supposition que l'on parte pour y rallier les phénomènes, toujours faut-il admettre un mouvement dans les aimans qui en sont cause, et recourir, comme Halley, à un espace libre au sein de la terre, dans lequel ces aimans puissent se mouvoir: car, d'un côté, les variations de l'aiguille sont trop régulières pour les attribuer à la formation et à la destruction accidentelles des mines der fer dans l'interieur de la terre; et de l'autre, elles sont trop considérables pour résulter de l'influence du magnétisme des corps célestes sur celui de la terre; on sait trop combien peu nos aimans les plus forts influent l'un sur l'autre quand leur distance n'est que de quelques pieds seulement, pour admettre que les corps célestes, considérés comme des aimans, puissent modifier sensiblement le magnétisme de la terre, dont ils sont si prodigieusement éloignés." Louis Bertrand, *Renouvellemens,* 279–280.

98 "...que, par conséquent, elle ne pourvoit point à l'alternative d'immersion et d'émersion des montagnes placées près de ce grand cercle [i.e., the equator], lesquelles cependant, tout aussi bien que les autres, sont revêtues de tous les caractères qui conviennent à des productions marines." Louis Bertrand, *Renouvellemens,* 285.

99 Louis Bertrand, *Renouvellemens,* 288.

100 Kenneth L. Taylor, "Earth and Heaven, 1750–1800: Enlightenment Ideas about the Relevance to Geology of Extraterrestrial Operations and Events," *Earth Sciences History* 17 (1998): 84.

In contrast are appeals to rare events, which Taylor describes as "the *idiosyncratic* appeal to extraterrestrial agents. In this other category I have in mind the invocation of an ephemeral or momentary extraterrestrial event, a notable instance being the physical influence of a comet's near passage."[101] In these terms Bertrand's view of the existence of an inner magnetic core moving diurnally and precessionally as shown in *Fig. 2*^eme^ is systemic; in contrast, the pole-to-pole translation of that core shown in *Fig. 1* is idiosyncratic. Although comets function as agents of renewal in the solar system, operating to cause the revolutions in the displacement of the seas, for Bertrand they also meant that an element of chance plays a noneliminable role in the renewals of the globe. The displacement of the ocean may be inevitable, as the general causes of comets are certain; however, specific displacements are rare events, and the timing and effects of any particular displacement are neither predictable nor fully specifiable.

A comparison with a contemporary of Bertrand's may be helpful. Lamarck's Aristotelian Theory of the Earth was perhaps more consistent with the meteorological context of the medieval Archimedean theories. Although both Bertrand's and Lamarck's Theories were cyclic, Lamarck's avoided the idiosyncratic appeal to rare events. To alter the Earth's center of gravity continually and gradually, Lamarck used tides and the sculpting of ocean basins, beginning his discussion with the declaration: "As long as the oceans have their own basin or, in other words, do not form a general liquid envelope around the earth, the globe's center of form will never exactly coincide with its center of gravity."[102] He explained that the Earth's center of gravity must be slowly and continuously displaced as water redistributes material and reshapes the surface of the Earth: "The result of this continuous change of mass... is to displace proportionally the earth's center of gravity, which becomes distinct from the real cen-

[101]Taylor, "Earth and Heaven," 84.

[102]Jean Baptiste Pierre Antoine de Monet de Lamarck, *Hydrogéologie ou Recherches sur l'influence qu'ont les eaux sur la surface du globe terrestre; sur les causes de l'existence du basin des mers, de son déplacement et de son transport successif sur les différens points de la surface de ce globe; enfin sur les changemens que les corps vivans exercent sur la nature et l'état de cette surface* (Paris: Chez l'Auteur; Agasse; Maillard, An 10, 1802); Jean Baptiste Pierre Antoine de Monet de Lamarck, *Hydrogeology*, trans. Albert V. Carozzi (Urbana: University of Illinois Press, 1964), 36–39.

ter or center of form."[103] Carozzi regards Lamarck's discussion as "a remarkable statement" demonstrating Lamarck's awareness that continents are continuously unloaded by stream erosion and therefore must be "slowly rising in order to maintain isostatic equilibrium. This paragraph represents one of the early speculations about isostasy."[104] Lamarck concluded:

> This discussion shows that any displacement of the ocean basin in a given direction corresponds to a similar movement of the earth's center of gravitation. Such a movable center, necessarily opposed to the greatest depths of the ocean, will have accomplished a complete revolution around the center of form when the ocean has completed its own revolution around the earth. This seems to have happened at least once.[105]

In a footnote to Lamarck's text, Carozzi comments that "This concept of the continual, simultaneous displacement of the ocean basin and the earth's center of gravity is a basic element in Lamarck's final theory on the genesis of the high plains out of which mountains have been carved."[106] Apparently unaware of the late medieval Archimedean theories of the Earth, Carozzi argues that Lamarck's theory was original because "he considered the shifting of the earth's center of gravity as the direct result of the displacement of the ocean basin and not as an independent process."[107] Since precisely the same may be said of some scholastic theories, it is inconsistent to regard those systemic theories as essentially cosmological while simultaneously hailing Lamarck's as an early statement of the geological concept of isostasy.

[103]Lamarck, *Hydrogeology*, 36.

[104]Lamarck, *Hydrogeology*, 37.

[105]Lamarck, *Hydrogeology*, 38–39. Lamarck could infer that it had happened at least once because of the ubiquitous presence of marine fossils on exposed land.

[106]Lamarck, *Hydrogeology*, 39.

[107]Lamarck, *Hydrogeology*, 39.

§ 4-iii. Shifting Centers from Adhémar to Croll

In *Révolutions, De la Mer* (1842) an obscure Paris mathematician, Joseph Alphonse Adhémar (1797–1862), synthesized the Theory of the Earth of Cuvier with the Ice Age of Louis Agassiz on the basis of quantitative astronomical cycles. Citing Cuvier, Adhémar began by noting that many times the sea has covered the land. Although many diverse hypotheses had been proposed to account for this great phenomenon, he wrote, all of them encountered insuperable difficulties. For example, if the water retreated into the interior of the Earth, why is the interior more dense than water? If Theorists such as Steno or Leibniz supposed that there were one or two immersions of the land caused by water proceeding from subterranean caverns, how could the water have returned many times to repeatedly cover the land? Adhémar announced that "C'est la solution de ce grand problèm qui fait le sujet de ce mémoire."[108] The key to his solution of the revolutions of the sea appeared in his first chapter's explanation of the astronomical cycle of precession (Table 31).

TABLE 31. Outline: Adhémar, Révolutions (1842)

Page	Section
1	Précession des équinoxes
21	Révolutions de la mer
23	Introduction
31	Équilibre des mers
42	Formation des glaciers
54	Température du globe
67	Diluvium du nord
78	Fossiles
86	Déluge
90	[Replies to Objections]
96	Conclusion

[108] Joseph Alphonse Adhémar, *Révolutions, De la Mer* (Paris: Carilian-Goeury et V. Dalmont, 1842), viii. Hereafter, "Adhémar."

Adhémar wrote that more than twenty years earlier he first entertained the idea that the precession of the equinoxes was the cause of the successive revolutions of the surface of the Earth.[109] In particular, one of his early sources was none other than Louis Bertrand, whose Theory he rejected because of its idiosyncratic character, but whose emphasis on bipolar shifts in the Earth's center of gravity he retained by substituting the regularity of precession for Bertrand's chance passing comet.[110] Adhémar's systemic explanation for the catastrophes of Cuvier presented them as the necessary consequence of the astronomical law of precession.[111] In Adhémar's system, geological catastrophes result from the action of precession upon the heating of the northern and southern hemispheres, causing the growth of ice sheets, or mountains of ice, at the cooler pole of the Earth. The mass of ice accumulating at one pole during one half of the precessional cycle then alters the center of gravity of the Earth.[112] Because of the altered center of gravity, the oceans are displaced toward the icy pole. Yet at the end of the half-cycle, when an icy hemisphere begins to warm, there is a slow period of melting during which the center of gravity gradually moves farther from the icy pole. This melting finally culminates in a debacle, undoing the oceanic polar bulge and submerging the

109 Adhémar, 21.

110 "Bertrand de Hambourg, dans un ouvrage imprimé en 1799 et qui a pour titre, *Renouvellement périodique des Continents*, avait déjà émis cette idée, que la masse des eaux pouvait être alternativement entraînée d'un hémisphère à l'autre par le déplacement du centre de gravité du globe. Or, pour expliquer ce déplacement, il supposait que la terre était creuse et qu'il y avait dans son intérieur un gros noyau d'aimant auquel les comètes par leur attraction communiquaient un mouvement de va-et-vient analogue à celui du pendule. Cette hypothèse, qui n'était appuyée sur aucun fait, a dû être rejetée. ¶ Celle que je propose, au contraire, dépend d'une des lois les mieux établies du système du monde; les effets de cette loi doivent être précisément ceux que j'ai indiquées, et le doute ne peut avoir lieu que sur la détermination des limites entre lesquelles les phénomènes doivent nécessairement se produire. On pourra discuter sur l'intensité plus ou moins grande des résultats, mais à moins de renverser les lois de l'équilibre, on ne peut nier l'existence du principe et refuser d'en admettre les conséquences. Je vais tâcher, au surplus, d'appuyer sur des chiffres la preuve des faits que je viens d'énoncer." Adhémar, 30.

111 "Dans mon hypothèse, les irruptions successives, considérées ici par Cuvier comme la cause évidente des couches qui composent la croûte de globe, seraient les conséquences nécessaires de la loi qui, tous les 10500 ans, fait passer le centre de gravité d'un hemisphère à l'autre." Adhémar, 84.

112 "On voit, par ce qui précède [quote from D'Aubuisson, *Géognosie*], que les géologues admettent qu'une grande partie des sédiments qui composent les couches successives du globe terrestre ont été déposés lentement dans un milieu tranquille, mais en même temps ils reconnaissent qu'à des époques plus ou moins éloignées, de grandes catastrophes avaient entièrement bouleversé la surface de la terre. Cuvier, principalement, se refuse à voir dans la dernière des révolutions du globe, le produit d'une action aussi lente que le serait le mouvement de la masse fluide entraînée par le déplacement régulier et insensible du centre de gravité." Adhémar, 85.

TABLE 32. **Theses of Adhémar's Révolutions, de la Mer (1842)**[a]

1	That because of the precession of the equinoxes, there arises an inequality between the totals of daylight and nighttime hours for the two hemispheres.
2	That this inequality produces a difference in the temperatures of the two hemispheres, and it is to this difference that one may attribute the ice of the two poles.
3	That the inequality which exists between the weights of the two ice masses necessarily displaces the Earth's center of gravity.
4	That the displacement of the Earth's center of gravity results in the displacement of water.
5	That this displacement of water should occur every 10500 years.

a. Adhémar, Révolutions, de la mer, 96: "1. Que par suite de la précession des équinoxes, il y a inégalité entre les sommes des heures de jour et de nuit des deux hemisphères;
2. Que cette inégalité produit une différence dans les températures correspondantes, et que c'est à cette différence que l'on doit attribuer celle des glaces des deux pôles;
3. Que l'inégalité qui existe entre les poids des deux masses glacées déplace nécessairement le centre de gravité;
4. Que du déplacement du centre de gravité résulte le déplacement des eaux;
5. Que ce déplacement des eaux doit avoir lieu tous les 10500 ans."

TABLE 33. **Phenomena confirming Adhémar's Révolutions, de la Mer (1842)**[a]

1	The ice sheet which, according to M. Agassiz and other geologists, has oftentimes covered the greater part of our hemisphere.
2	The death of elephants in the ice where they were driven by the waters.
3	The presence upon our continents, during several thousands of years, of a tranquil sea in the bosom of which were formed the stratified beds which contain fossils.
4	The periodical repetition of the same phenomena, from which result the different stages of beds that compose the crust of the globe.
5	The violent irruption which has furrowed the northern countries of Europe.
6	Finally, the unequal distribution of water in the two hemispheres.

a. Adhémar, Révolutions, de la mer, 98–99:
"1. La calotte glacée qui, selon M. Agassiz et d'autres géologues, a recouvert autrefois la plus grande partie de notre hemisphère;
2. La mort des eléphants dans les glaces où ils ont été chassés par les eaux;
3. La présence, pendant plusieurs milliers d'années au dessus de nos continents, d'une mer tranquille dans le sein de laquelle se seraient formées les couches stratifiées qui contiennent les fossiles;
4. La répétition periodique des mêmes phénomènes, d'où résultent les différents étages des couches qui composent l'écorce du globe;
5. L'irruption violente qui a labouré les contrées septentrionales de l'Europe;
6. Enfin, l'inégale répartition des eaux dans les deux hémisphères."

continents beneath a torrent. For example, Adhémar argued that, during Noah's deluge, precession caused the last shift in the Earth's center of gravity, which began the Tertiary (*Troisième*) époque.[113] Table 32 provides Adhémar's own summary of his Theory of the astronomically-regulated "revolutions of the sea." Table 33 lists the particular phenomena (culled from Cuvier, Humboldt, Agassiz, and Lyell) which Adhémar regarded as confirming necessary consequences of the theory.[114]

Adhémar substituted the systemic cycle of precession for Louis Bertrand's idiosyncratic passing comet, but Adhémar represents the end of the long line of Archimedean theories explaining the disposition of the land and the sea in terms of changes in the Earth's center of gravity. There were other contemporaries who echoed the fourteenth-century theories in various ways,[115] but Adhémar's Theory was soon appropriated by James Croll in a manner that transformed it by dispensing with the center of gravity mechanism altogether. Croll retained Adhémar's emphasis upon astronomical cycles including precession, and like Adhémar (though for different reasons) used them to explain the origin of ice ages:

> Croll believed that ice ages are caused by changes in the distance between the earth and the sun, as measured on December 21. When this distance exceeds a critical value, northern hemisphere winters are cold enough to trigger an ice age; when this distance is less than a critical value, an ice age occurs in the southern hemisphere. During glacial epochs, orbital eccentricity is so large that these critical limits are often exceeded.[116]

After receiving a rigorous mathematical formulation by Milutin Milankovitch in the third and fourth decades of the twentieth century, the Croll-Milankovitch theory is now widely accepted on the basis of geological evidence discovered in the 1970s.[117]

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[113]Adhémar, 87.

[114]A more extensive explanation of Adhémar's Theory is given by John Imbrie and Katherine Palmer Imbrie, *Ice Ages: Solving the Mystery* (Cambridge: Harvard University Press, 1979), chapter 5.

[115]For example, Huggett describes the polar wandering theory of John Lubbock (1848), which resembled the process outlined by Oresme (Table 28 on page 241) and advocated by Alexandro Alexandri (1522; cf. footnote 356 on page 190). For these and related late-nineteenth century debates see Richard Huggett, *Cataclysms and Earth History: The Development of Diluvialism* (Oxford: Clarendon Press, 1989), 118–121.

[116]Imbrie and Imbrie, 84. Croll's astronomical theory is explained in Imbrie and Imbrie, chapter 6.

The vignettes surveyed in this chapter show that Copernicus provided neither the beginning nor the end of theories about the significance of changes in the Earth's center of gravity. The cases of Adhémar and Croll represent the later legacy of center-of-gravity considerations prominent in medieval meteorologies and in Theories of the Earth. These considerations were neither essentially cosmological, meteorological, nor geophysical, but highly mobile in crossing contextual boundaries.

§ 5. Conclusion

Cosmological considerations were at times of central significance in that some Theories of the Earth could be presented as a branch of cosmology. However, this was not always the case, since many Theorists from Descartes to Deluc (like many meteorologists before them) distinguished their investigations from cosmology in some manner.[118] Even if they were not presented as a branch of cosmology, Theories of the Earth might invoke cosmology by critically relying upon cosmological *agents* such as comets, cosmological *events* such as astrological conjunctions, cosmological *laws* such as doctrines of inertia or relative place, quantitative cosmological *constraints* such as those involving the heat of the sun or the figure of the Earth; cosmological *theories* such as those regarding the formation of planets; meta-cosmological *principles* such as the principle of sufficient reason, the uniformity of space, or a correspondence between the macrocosm (universe) and microcosm (Earth or human body); or various cosmological *conjectures* regarding the Plurality of Worlds. Yet when a Theory relied upon cosmological considerations a variety of cosmologies might be invoked (not all of which

[117]Cf. Imbrie and Imbrie. John Imbrie is one of the geologists who made these discoveries.

[118]As noted on page 126, toward the end of the eighteenth century "geology" came to refer to Theories of the Earth precisely in order to distinguish them from cosmology. Even Descartes' *Principia* separated the Part devoted to the Earth from the Part explicating his cosmology, just as he had distinguished cosmology from the preceding Parts devoted to epistemology and metaphysics. This was the case notwithstanding the fact that the Parts were linked by a continuous chain of logical reasoning to the extent that, for Descartes, the plausibility of his Theory of the Earth on other grounds was to be taken as commending his epistemology and metaphysics (see "Baptizing Descartes," beginning on page 602).

entailed cosmogonies). In different ways Burnet and Fontenelle built on Cartesian foundations; Buridan and Kircher on scholastic perspectives; William Gilbert and Francis Bacon upon a geocentric magnetic cosmology; while Whiston and Woodward each invoked Newtonian ideas. Like the Plurality of Worlds tradition, Theories of the Earth flourished within diverse cosmological orientations. Neither Copernican (*pace* Collier) nor Cartesian (*pace* Roger) nor Newtonian (*pace* Nicolson) cosmologies, nor mechanistic science as a whole (*pace* Greene and Kubrin) qualifies as a cosmological *sine qua non* of theories of the Earth. Theories of the Earth were adaptable to a variety of cosmological habitats, with few essential conceptual preconditions.

It would be a mistake to suggest that *any* use of cosmological considerations upon theorizing was peculiar to Theories of the Earth, whereas nineteenth-century geology became entirely free of cosmology. There is a great difference between constructing a Theory of the Earth as a branch of cosmology (as did some Theorists, including later Theorists such as Kant and Hay), and constructing a Theory of the Earth which takes contemporary cosmology into account (as did many Theorists, like most nineteenth-century geologists and geophysicists).[119] Theorists' use of cosmological constraints was not always entirely different in principle than the acceptance by many nineteenth-century geologists and geophysicists of the nebular hypothesis as a significant context for theorizing upon the physics of the Earth's crust, the composition of its core, or the rate of global cooling and past climatic change.[120]

[119]Cf. Philip J. Lawrence, "Heaven and Earth—The Relation of the Nebular Hypothesis to Geology," in *Cosmology, History, and Theology*, ed. Wolfgang Yourgrau and Allen D. Beck (New York: Plenum Press, 1977), 253–281.

[120]In a more recent example, Peter Ward (a geologist) and Donald Brownlee (an astronomer) bring cosmological considerations to bear upon geological theorizing about the Earth's past in support of a vision of natural order and historical contingency much in line with the sensibility of Gould's *Wonderful Life*: "it is likely that a planet's *history*, as well as its environmental conditions, plays a part in determining which planets will see life advance to animal stages. How many planets, otherwise perfectly positioned for a history replete with animal life, have been robbed of that potential by happenstance? An asteroid impacting the planet's surface with devastating and life-exterminating consequences. Or a nearby star exploding into a cataclysmic supernova. Or an ice age brought about by a random continental configuration that eliminates animal life through a chance mass extinction. Perhaps chance plays a huge role." Peter D. Ward and Donald Brownlee, *Rare Earth: Why Complex Life is Uncommon in the Universe* (New York: Copernicus, 2000), xxiii (original italics).

It is past time to move away from a historiography of Theories of the Earth that is preoccupied with a view of the Scientific Revolution which assumes that revolutionary developments in an exact science like astronomy were necessary to drive the slower growth of empirical sciences such as natural history.[121] Only within the shadow of such a historiography did it make sense to regard theories of the Earth as *necessarily* a post-Copernican endeavor, *i.e.*, becoming conceptually possible only after the Earth became regarded as a planet. The desire to trace a controlling influence of Copernicanism or the mechanical worldview upon the Earth sciences has not fulfilled its promise. Developments were more contingent and complex than monocausal accounts and rigid philosophical definitions allow. Views of the Scientific Revolution itself have been revised in ways that call global explanations into question, and in the process new interpretative themes have raised other aspects of seventeenth-century natural knowledge to equal prominence, such as the significance of the change from belief in solid crystalline spheres to fluid heavens, the proliferation of chymical philosophies (both within and without mechanical philosophy), and the multiplication of alternative if now-forgotten geocentric cosmologies. Further investigations incorporating these new perspectives will throw needed light upon seventeenth-century Theories of the Earth and the origin of the tradition.

[121] This assumption has been contested by Yushi Ito, "Earth Science in the Scientific Revolution" (Ph.D. dissertation, University of Melbourne, 1985).

CHAPTER 3 On the Edge of Geology

§ 1. Introduction

The relations between Theories of the Earth and geology are even more problematic than is the case with cosmology, in part because of a legacy of familial quarrels that attended the emergence of geology as a technical tradition in the early nineteenth century. For this reason it will be necessary in the sections that follow to avoid analysis of historiographical principles *in vacuo*; rather, with respect to each point of contention close attention will be given to one or a few specific Theories to extend the historiographical arguments introduced in Chapter 1. These case studies are in no way superfluous to a clearer formulation of the historiographical issues. The historiographical discussions early in this chapter may seem elementary to professional historians, but they may be of some interest to geologists and should enable any reader to follow the arguments of the later sections. The main purpose of the chapter is to show how understanding Theories of the Earth as a contested textual tradition clarifies some aspects of the emergence of geology. Moreover, in an introductory overview some benefits accrue from surveying a small sample of diverse Theories.

Most laudably, Jacques Roger's demarcation attempt was designed in part to promote the understanding of Theories of the Earth as a separate genre concerned in its own ways with historical understanding of the Earth, not anachronistically to be regarded as an attempted but failed exercise in historical geology. Unfortunately, the latter attitude remains common. Earth Theorists' intellectual habits often seemed foreign to nineteenth-century geologists who sought to establish their profession as a specialized and consensual field of inquiry, as a technical tradition with collective research goals deploying shared investigative techniques. With hindsight, Theories of the Earth seemed to them to have been characterized by intractable controversies arising from the apparently unchecked proliferation of conceptual schemes, a circumstance which they alleged reflected the inappropriate goals and inadequate constraints of non-stratigraphic aims and methodologies.[1]

Perhaps the surest sign that a historian has his or her eye on early nineteenth-century geology when retrospectively looking back on Theories of the Earth is when the latter are dismissed as merely speculative endeavors because their writers did not follow the stratigraphical methods which became so productive in the early nineteenth century. As a typical example, Charles Gillispie distinguished Theories of the Earth from geology on precisely these grounds:

> Buffon, the relation of whose system to Genesis was very attenuated, was often as imaginative as the generally orthodox Burnet. *It was in its essentially speculative ends, not in the orthodoxy of its theological implications, that cosmogony differed from scientific geology.*[2]

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1 See "Roger's Demarcationist Criteria: Global Directionalism," beginning on page 211. An alternative perspective to Roger's demarcationist agenda—which retains Roger's concern for historical understanding of Theories of the Earth as something other than a failed exercise in historical geology—is introduced in "Textual versus Technical Traditions," beginning on page 79, knowledge of which is assumed throughout this chapter. Note that some of the controversies in Theories of the Earth were continuous with geological disputes, including the relative merits of structural relations and fossils for correlating formations.

Anthony Hallam's comments are more judicious, despite his characterization of nonstratigraphical methods as speculative:

> Generations of British and American geologists have been indoctrinated as students with the view that the English canal surveyor William Smith (1769-1839) was the father of stratigraphy. This has never been accepted, with good reason, on the European continent, where stratigraphy has been perceived as emerging gradually from a long tradition dating well back into the eighteenth century, with the seminal influence deriving from Werner.... The beginning of an historical approach to the earth was to be found in the speculative theories of the cosmogenists of the late seventeenth and early eighteenth centuries, against which there was such a strong empiricist reaction several decades later.[3]

Hallam suggests that as a result of an interesting chain of historical contingencies Theories of the Earth were of great significance for the emergence of geology. The Theory of the Earth of Peter Simon Pallas (1747–1811) corroborates this assessment.

Pallas traveled extensively through Russia in the early 1770s, publishing a five-volume travel account that was widely read for its geological observations. In 1777 he presented a Theory of the Earth to the Academy of Sciences at St. Petersburg.[4] Pallas' Theory of the Earth was often cited for its schematized description of the structure of mountains, according to which major mountain ranges of the first order consist of a central granite axial core sur-

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[2] Charles Coulston Gillispie, *Genesis and Geology: A Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790–1850* (Cambridge: Harvard University Press, 1951), 42, italics added; hereafter Gillispie, *Genesis and Geology.* Actually, Burnet was not widely regarded as "generally orthodox"; see "The Idiosyncrasy of Burnet," beginning on page 496. The rest of this chapter extends the earlier discussion of the rhetorical use of "speculation" in "Theories and Facts," beginning on page 52.

[3] Anthony Hallam, *Great Geological Controversies*, 2d ed. (Oxford: Oxford University Press, 1989), 65; hereafter Hallam, *Great Geological Controversies*.

[4] Pallas' theory was published by the Academy as Peter Simon Pallas, "Observations sur la Formation des Montagnes & les changemens arrivés au Globe," *Acta Academiae Scientiarum Imperialis Petropolitanae* 1 (1777): 21–64. An alternate draft, written in German, was published at Frankfurt and Leipzig the following year; Peter Simon Pallas, *Betrachtungen über die Beschaffenheit der Gebürge und Beranderungen der Erdfugel, besonders in Beziehung auf das Rußische Reich.... Akademie der Wissenschaften ben 23ten Junius 1777...* (Frankfurt und Leipzig, 1778). The German version, slightly longer than the French, is translated in Albert V. Carozzi and Marguerite Carozzi, "Reevaluation of Pallas' *Theory of the Earth* (1778)" *Archives des Sciences* 1991, 44: 1–105 (reprinted Genève: Société de Physique et d'Histoire naturelle, 1991); hereafter Pallas (1778). The accuracy of Pallas' field observations has been confirmed by Albert V. Carozzi and Marguerite Carozzi in their commentary on the German edition. On the other hand, they claim that his Theory of the Earth was inaccurate because he contrived it for largely political reasons. In a review of their edition I suggest that this interpretation is unpersuasive; Kerry Magruder, *Earth Sciences History* 1994, 13: 190-191. The present discussion of Pallas follows part of this review.

rounded on either side by bands of nonfossiliferous primitive *Schiefer* (schistose rocks, frequently containing rich veins and ores). Mountain chains of the second and third orders add bands of secondary limestones, and then shales and sandstones. To support this conclusion Pallas began his exposition with a relatively lengthy description of the mountains and steppes of Asia, interspersed with reconstructions of their inferred changes over time. In the recent past, Pallas suggested, great underground fires and eruptions beneath the Indian Ocean had produced a northward-rushing deluge that sculpted various features of the Asian continent while depositing heaps of animal remains in Siberia (such as elephant ivory or a frozen rhinoceros carcass). The contingent action of such a torrent, moving in a specific direction across a particular region at a unique time, was reconstructed on the basis of phenomena Pallas observed in the field during his travels. This event was neither a universal deluge proven by appeal to the scriptural account of Noah, nor was it a general cause deduced from the first principles of physics acting everywhere and always on the face of the Earth.

Pallas was often cited by Theorists of the Earth after him such as Saussure, Deluc, and Cuvier.[5] His Theory illustrates the inadequacy for the history of early geology of once common analytical categories such as Neptunist vs. Plutonist. Pallas insisted that one should combine diluvial, volcanic, and other causes to account for the Earth's history, and "not refer only to a single one."[6] This theme was echoed by many of his contemporaries. Instead of the traditional historiographical preoccupation with water vs. fire, the open question with regard to Pallas' Theory of the Earth and others of the same period is more one of privileged evidence than preferred agent, *i.e.*, the degree to which they regarded travel and field observation, such as his account of the Urals, as the primary kind of evidence required for the reconstruction of the Earth's past.

[5] Although treating a related topic, Alexander von Humboldt did not mention Pallas in his discussion of the pyramidal shape of the southern tips of continents; cf. footnote 3 on page 368.

[6] Pallas (1778), 30.

In the late eighteenth century Theorists faced an embarrassment of riches regarding available potential evidence. There were far more "facts" to be investigated as possible evidence for any given question than there were consensual protocols for their organization and interpretation.[7] Sources of potential evidence for Theorists included observations in the field, the cabinet, the mine and the laboratory, involving rocks, fossils, landforms and mineralogical formations. Fossil evidence was central to the Theories of Steno, Woodward, Scheuchzer, and Cuvier, among others, while mineralogists such as Wallerius and Werner emphasized the succession of formations. Landforms were of increasing interest in the eighteenth century, while experimental work in the laboratory, foundry, or factory was important to Theorists as diverse as Buffon and James Hall.[8] Instead of focusing on the sequential order of mineralogical formations in the field, Hutton characterized himself as a natural philosopher reasoning upon the chemical process of mineralization rather than a natural historian or historical geologist concerned with the potential stratigraphical significance of fossils.[9] The interplay between these and other kinds of evidence and the kinds of accounts Theorists wished to provide about the Earth was complex: cabinet, museum and laboratory studies were not necessarily tied to genetic or steady-state sensibilities, and field evidence was not invariably associated with historical views. For example, Hutton's nondirectionalist views were supported with fieldwork, while Hutton expressed pointed reservations about the value of laboratory analogies (although

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7 For a contrasting assessment see the comment of Martin Rudwick on page 56 ff.

8 On landforms see Gordon L. Herries Davies, *The Earth in Decay: A History of British Geomorphology, 1578-1878* (New York: American Elsevier Publishing Company, 1969), and Richard J. Chorley, Antony J. Dunn and Robert P. Beckinsale, *Geomorphology Before Davis*, vol. 1 of *The History of the Study of Landforms, or the Development of Geomorphology*, 2 vols. (London: Methuen & Co., Ltd.; New York: John Wiley, 1964); François Ellenberger, "Les Méconnus: Eighteenth Century French Pioneers of Geomorphology," in *History of Geomorphology: From Hutton to Hack*, ed. Keith J. Tinkler. Binghamton Symposia in Geomorphology: International Series, no. 19 (Boston: Unwin Hyman, 1989), 11–36. For the under-recognized role of laboratory experiments in early geology see Sally Newcomb, "Contributions of British Experimentalists to the Discipline of Geology: 1780–1820," *Proceedings of the American Philosophical Society* 134 (1990): 161–225.

9 In a 1770 letter to John Strange, Hutton explained: "My attention has been chiefly upon the various substances that enter into the composition of the mineral kingdom in general; and being neither botanist nor zoologist in particular, I never considered the different kinds of figured bodies found in strata further than to distinguish betwixt animal and vegetable, sea and land objects, the mineralization of those objects being more the subject of my pursuit than the arrangement of them into their classes." Cited by Dennis R. Dean, *James Hutton and the History of Geology* (Ithaca: Cornell University Press, 1992), 9; hereafter Dean, *James Hutton*.

these reservations were not shared by Huttonians such as James Hall).[10] And in his historically-contingent account Georges Cuvier privileged paleontological evidence obtained through a combination of geognostic fieldwork and anatomical study as a museum naturalist, but he also countered anticipated objections to his Theory with detailed considerations of textual, philological, antiquarian, astronomical, and mineralogical evidence.[11] The only safe preliminary generalization is that the preferred kinds of evidence and, once in hand, the proper means of interpreting that evidence, were significant questions of ongoing debate.

Pallas' Theory of the Earth was a "big picture" that provided a framework for geological theorizing in which travel and field observations were critical, especially from underexplored areas such as Russia. As a consequence, Pallas' Theory suggests that sweeping contrasts cannot be sustained between arm-chair Theorists of the Earth and historical geologists as observers in the field. Theories of the Earth were potential contributors to a variety of disciplines, including cosmology and geology as well as geography, meteorology, chemistry, and natural history. Fieldwork of enduring geological value could be nurtured within the Theory of the Earth tradition, but the diversity of a textual tradition entailed that Theorists had to contend with a broad range of evidence. Despite the significance of Theories of the Earth for geology, it

[10] Hutton's fieldwork is discussed below; on his reluctance to privilege experimental evidence see Rachel Laudan, *From Mineralogy to Geology: The Foundations of the Earth Sciences, 1660–1830*, Science and Its Conceptual Foundations, ed. David L. Hull (Chicago: University of Chicago Press, 1987), 130–134.

[11] For example, in the 1825 edition Cuvier greatly expanded his essay with new discussions, including an enlarged version of the already considerable treatment of ancient chronology; cf. "L'histoire des peuples confirme la nouveauté des continens" and "L'antiquité excessive attribuée à certains peuples n'a rien d'historique," Cuvier, *Discours sur Les Révolutions* (1825), 165–241. These sections were translated as "The History of Nations confirms the Newness of the Continents" and "The very remote Antiquity attributed to certain Nations is not supported by History"; Cuvier, *Theory of the Earth* (1827), 137–183 (the parallel passage in the 1817 translation is less than 33 pages, pp. 132–165). Similarly, five pages devoted to astronomical considerations and the zodiac in the 1817 translation (pp. 165–170) were expanded to 55 pages in the 1827 translation (pp. 183–238); cf. Cuvier, *Discours sur Les Révolutions* (1825), 221–281. Georges Cuvier, *Discours sur Les Révolutions de la surface du globe, et sur les changemens qu'elles ont produits dans le règne animal,* 3d ed. (Paris, et à Amsterdam: chez G. Dufour et Ed. d'Ocagne, 1825), hereafter Cuvier, *Discours sur Les Révolutions* (1825); this edition is translated as Georges Cuvier, *Essay on the Theory of the Earth. By Baron G. Cuvier... with Geological Illustrations, by Professor Jameson. Fifth edition, Translated from the last French edition, with Numerous Additions by the Author and Translator, trans. Robert Kerr* (William Blackwood, Edinburgh; and T. Cadell, Strand, London, 1827); hereafter Cuvier, *Theory of the Earth* (year of publication). The Kerr-Jameson translation is generally word-for-word, but not always free from interpretation—for example, in the following sentence "or universal deluge" is an addition not found in Cuvier: "In order to recover some truly historical traces of the last grand *cataclysma*, or universal deluge, we must go beyond the vast deserts of Tartary...."; Cuvier, *Theory of the Earth* (1817), 159. Cuvier's early editions are cited in footnote 83 on page 307.

remains the case that Theorists often employed methodologies other than fieldwork to pursue questions other than the purely stratigraphical, and consequently their historical character cannot adequately be appreciated if they are analyzed as an anticipation of nineteenth-century historical geology. Therefore it is inappropriate to evaluate any particular Theory of the Earth in terms of its individual longevity or resemblance to lasting geological knowledge. Discarded Theories were in large part successful if they provided a systematic framework for posing particular research problems by which their own deficiencies were exposed. Pallas conceded such an eventual fate for his own system, confessing that his hypotheses could "never be presented as proofs," and were not "entirely free of difficulties," but attained only a relative "degree of perfection."[12] The historiography of Theories of the Earth as a textual tradition and the historiography of early geology as a technical tradition overlap considerably but are not the same.[13]

§ 2. Hutton and the Whig Interpretation of Geology

Theories of the Earth are difficult to understand. Some are of quite different character than later geological works. Many are quite unlike modern geology except that both deal with the Earth, and therein lies a temptation for the geologist or historian who seeks to understand what Theorists of the Earth were up to. The particular temptation called presentism or the "Whig Interpretation of History" consists of a disposition to read the present back into the past, a tendency anachronistically to evaluate past events according to present knowledge. According to Butterfield, presentist or "Whig" interpretations of history strive to categorize

[12] Peter Simon Pallas, *Pallas' Theory of the Earth in German (1778): Translation and Reevaluation*, trans. and ed. Albert V. Carozzi and Marguerite Carozzi (Extrait des *Archives des Sciences*, 1991, 44; éditées par la Société de Physique et d'Histoire naturelle de Genève, 1991), 36. See comments above on the epistemological significance of Ellenberger's distinction between Theories of the Earth and "The Theory of the Earth," page 141.

[13] A similar point was elucidated with respect to Theories of the Earth and geognosy in "Geognosy and the Wernerian Adaptive Radiation," beginning on page 116. Cf. the hints in footnote 7 on page 10 that Theories of the Earth may be regarded as the Cambrian period of the history of geology, and also the analysis of their chief differences in "Textual versus Technical Traditions," beginning on page 79.

historical figures as either progressive or reactionary, where progressives hold ideas or follow methods like our own while reactionaries differ.[14]

As a consequence of this search for similarities, past views which prove assimilable to present knowledge are heralded as anticipations and precursors on humanity's road to truth. Such ahistorical assessments "praising the precursor" ignore the ways historical actors understood their worlds. Even when particular propositions appear most similar to modern ones, dissimilar beliefs that jar a modern eye may have been integrated with them into a general endeavor with quite different aims and meanings than presentist interpretations suggest. For example, Kepler's methods do not conform to modern standards in astronomy and cosmology. Yet some of Kepler's conclusions may be made to appear up-to-date by selective abstraction, discarding as if it had never existed the Neoplatonic theological framework in which he formulated what are now known as Kepler's three laws.[15] Precisely the same kind of maneuver is attempted by those who ignore Newton's alchemical work with its emphasis upon

[14] By "Whiggism" or "presentism" I mean only the committing of historical anachronism as described by Herbert Butterfield; there are other sources of anachronism and other ways of taking the present into account, but these are not relevant to the argument here. As every beginning student of history learns, Butterfield gave the fallacy its common name in a classic essay of the same title, describing the presentist orientation this way: "It is part and parcel of the whig interpretation of history that it studies the past with reference to the present; and though there may be a sense in which this is unobjectionable if its implications are carefully considered, and there may be a sense in which it is inescapable, it has often been an obstruction to historical understanding because it has been taken to mean the study of the past with direct and perpetual reference to the present. Through this system of immediate reference to the present-day, historical personages can easily and irresistibly be classed into men who furthered progress and the men who tried to hinder it; so that a handy rule of thumb exists by which the historian can select and reject, and can make his points of emphasis. On this system the historian is bound to construe his function as demanding him to be vigilant for likenesses between past and present, instead of being vigilant for unlikenesses; so that he will find it easy to say that he has seen the present in the past, he will imagine that he has discovered a 'root' or an 'anticipation' of the 20th century, when in reality he is in a world of different connotations altogether, and he has merely tumbled upon what could be shown to be a misleading analogy." Herbert Butterfield, *The Whig Interpretation of History* (Originally published in 1931; reprinted New York: W. W. Norton and Company, 1965), 11–12. For a defense of other ways of taking the present into account which are not relevant here see A. R. Hall, "On Whiggism," *History of Science* 21 (1983): 45–59, and David L. Hull, "In Defense of Presentism," *History and Theory* 18 (1979): 1–15.

[15] Interpretative rather than Whiggish historiography is exemplified by recent Kepler scholars; cf. the work of Peter Barker and Bernard Goldstein, including Peter Barker and Bernard R. Goldstein, "Theological Foundations of Kepler's Astronomy," *Osiris* 16 (2000): forthcoming; Peter Barker and Bernard R. Goldstein, "Distance and Velocity in Kepler's Astronomy," *Annals of Science* 51 (1994): 59–73; Peter Barker and Bernard R. Goldstein, "The Role of Comets in the Copernican Revolution," *Studies in History and Philosophy of Science* 19 (19??): 299–319; Peter Barker, "The Optical Theory of Comets from Apian to Kepler," *Physis* 30 (1993): 1–25; and Peter Barker, "Understanding Change and Continuity," in *Tradition, Transmission, Transformation*, ed. F. Jamil Ragep and Sally P. Ragep, 527–550 (Leiden: Brill, 1996).

attractive forces and the activity of matter and dismiss it as irrelevant to the development of his mathematical physics.[16]

An immediate clarification is required with respect to any reassessment of Theories of the Earth. Avoiding the abstractions of presentism requires a constant vigilance not simply to conflate Theories of the Earth with geology; as noted above, Jacques Roger provides an admirable example of this vigilance for such was his motivation in distinguishing Theories of the Earth and geology as different mentalities or separate conceptual genres. Yet against the conventional view that Theories of the Earth were wholly displaced by and incommensurable with the emerging profession of geology, I am arguing for dialectical relationships in which Theories of the Earth were juxtaposed with and sometimes variously appropriated by geology. In so doing, as part of the necessary task of identifying overlapping points of contact between the two traditions, there is an obvious danger of "precursoritis," of searching for anticipations and overemphasizing their similarities. So to avoid presentist distortions it is incumbent upon me to refrain from any suggestion that the anticipations or similarities are so great as to dissolve the two traditions into one another. Rather, between later Theories of the Earth and early geology important dissimilarities and discontinuities remain, particularly those which relate to the contrasting character of textual and technical traditions. Because Theories of the Earth were a textual tradition the diversity of practices they encompassed remained too disparate to be conflated with geology.[17]

If, then, the search for geological precursors leads to an inadequate understanding of Theories of the Earth, the remainder of this section will address the shortcomings of presentism for understanding the disciplinary history of geology. For an example in geology of the misleading tendency to "praise the precursor" we may turn to typical characterizations of

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16 Betty Jo Teeter Dobbs opened up explorations of the significance of Newton's alchemy; cf. Betty Jo Teeter Dobbs, *The Foundations of Newton's Alchemy, or The Hunting of the Greene Lyon* (Cambridge: Cambridge University Press, 1975) and Betty Jo Teeter Dobbs, *The Janus Faces of Genius: The Role of Alchemy in Newton's Thought* (Cambridge: Cambridge University Press, 1991).

17 See "Textual versus Technical Traditions," beginning on page 79.

James Hutton's Theory of the Earth.[18] Scarcely a textbook history of geology neglects to mention James Hutton, but despite the familiarity of his name Hutton is often misunderstood. Explicitly concerned with the philosophical problem of understanding the Earth teleologically, as the product of design, Hutton's system was premised on the twin propositions that perpetual habitability constitutes the overall purpose of the Earth and that continual renovation is required to ensure it.[19] This renovation is accomplished through a three-step cycle:

- *erosion*, which levels the exposed land;
- *consolidation* of sediments transported to the bottom of the sea; and, finally,

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[18] Some of the following paragraphs draw substantially upon my review of Dennis R. Dean, *James Hutton and the History of Geology* (Ithaca: Cornell University Press, 1992), in *INHIGEO Newsletter* (published by the International Commission on the History of Geological Sciences), no. 25, for 1992 (issued 1993), pp. 38-39. The various publications of Hutton's Theory are cited in footnote 192 on page 107.

[19] Hutton expressed these views repeatedly, as illustrated by the following long passage (emphasis added): "Therefore, a proper system of the earth should lead us to see that wise construction, by which this earth is made to answer the purpose of its intention, and to preserve itself from every accident by which the design of this living world might be frustrated. For, as this world is an active scene, or a material machine moving in all its parts, we must see how this machine is so contrived, as either to have those parts to move without wearing and decay, or to have those parts, which are wasting and decaying, again repaired. A rock or stone is not a subject that, of itself, may interest a philosopher to study; but, when he comes to see the necessity of those hard bodies, in the constitution of this earth, or for the permanency of the land on which we dwell, and when he finds that there are means widely provided for the renovation of this necessary decaying part, as well as that of every other, he then, with pleasure, contemplates this manifestation of design, and thus connects the mineral system of this earth with that by which the heavenly bodies are made to move perpetually in their orbits. It is not, therefore simply by seeing the concretion of mineral bodies that a philosopher is to be gratified in his intellectual pursuit, but by the contemplation of that system in which the necessary revolution of this earth, while at present it serves the purpose of vegetation, or the fertility of our soil, is the very means employed in furnishing the materials of future land. I have concluded a certain system according to which things will be changed, without any accident or error. It is by tracing this regular system in nature that a philosopher is to perceive the wisdom with which this world has been contrived; but, he must see that wisdom founded upon the aptitude of all the parts to fulfil the intention of the design; and that intention is to be deduced from the end which is known to be attained." James Hutton, *Theory of the Earth, with Proofs and Illustrations*, 2 vols. (Edinburgh: for Cadell and Davies, London, 1795), 1: 275–8; emphasis added. Brooke rightly cautions against tendencies to homogenize teleological reasoning or to conflate it with Christian natural theology: "The fact that natural theology could be used both to attack and defend Christianity may be confusing, but that very ambivalence also helps to account for its resilience. Without additional clarification, it is not always clear to the historian (and was not always clear to contemporaries) whether proponents of design were arguing a Christian or deistic thesis." Brooke, *Science and Religion*, 193–4. Brooke elaborates: "The Huttonian cycles of elevation, erosion, deposition, and consolidation were grounded in teleological reasoning, which assumed that nature (and/or God) purposed the maintenance of plants and animals. The insertion of that ambivalence is deliberate because, whether or not he was familiar with the Kantian critique, Hutton seems to have perceived that teleological reasoning could play a regulative role without having to be attached to a theological base. His own references to 'infinite power and wisdom' were helpful to those who sprang to his defense, but he was equally at home when denying the 'possibility of anything happening preternaturally or contrary to the common course of things.' A role for natural theology is visible in Hutton's science, but in precisely that ambivalent manner that we identified...." Brooke, *Science and Religion*, 215. A study of the role of teleology in Hutton's work is R. Grant, "Hutton's theory of the earth," in *Images of the Earth: Essays in the History of the Environmental Sciences*, ed. Ludmilla J. Jordanova and Roy S. Porter, BSHS Monographs, no. 1 (Chalfont St. Gilles, England: British Society for the History of Science, 1978), 23–38.

- *elevation* of consolidated rock to form new continents (with a concurrent subsidence of old continents to form new sea basins).

This cycle has the potential to recur perpetually, thus preventing any past or future decay of the Earth.

That the Earth has in fact endured long enough for the cycle to recur, Hutton concluded, is manifest in tilted formations such as those he described near Jedburgh, Scotland. There in the banks of the Jed river, he argued, remnants of at least one previous "world" are evident in vertical strata now overlain by horizontal strata (Figure 31). To explain the present configuration of strata near Jedburgh Hutton reconstructed a series of events we may enumerate as follows:

1. **Erosion** of a pre-existing continent and transport of sediments to the bottom of the sea, where there occurred the....
2. horizontal deposition and **consolidation** of *schistus* strata.
3. **Elevation** of the consolidated *schistus* (which event also tilted the strata to a vertical position) to form a new continent in this location above the surface of the sea.

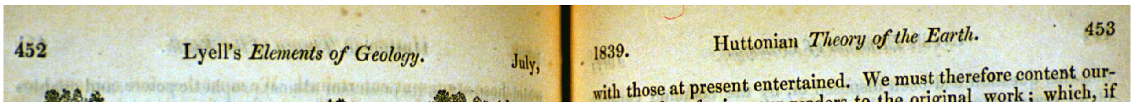
This series of events accounting for the tilted strata corresponds to the three-step cycle just outlined, but to explain the overlying strata requires an additional turn or two of the cycle:

4. **Erosion** of the exposed vertical strata of the second continent creating the layer of puddingstone (conglomerate) above sea-level.
5. **Sinking** of the second continent (composed of the vertical strata and puddingstone) beneath the sea.
6. **Erosion** of a different continent in a nearby location and transport of its sediments to the bottom of the sea, where there occurred the...
7. horizontal deposition and **consolidation** of the sandstone strata.
8. **Elevation** of the strata (now including the consolidated sandstone, without further tilting) to form a new continent (the second in this location) which we now behold above the surface of the sea.

Hutton corroborated his theory of the elevation of strata and the intrusion of new rock formed by fire from below, through his study of the principles of mineralogical chemistry[20]

[20] On Hutton's theory of heat and the relations between James Black, James Hall, and James Hutton see Arthur L. Donovan, *Philosophical Chemistry in the Scottish Enlightenment* (Edinburgh: Edinburgh University Press, 1975); Arthur L. Donavan, "James Hutton, Joseph Black, and the Chemical Theory of Heat," *Ambix* 25 (1978): 176–190; Patsy Gerstner, "James Hutton's Theory of the Earth and His Theory of Matter," *Isis* 69 (1968): 26–31; and Patsy Gerstner, "The Reaction to James Hutton's Use of Heat as a Geological Agent," *British Journal for the History of Science* 5 (1971): 353–362.

and observations of field evidence such as granitic intrusions and tilted strata.[21] Thus on philosophical grounds, confirmed by empirical evidence combining fieldwork and chemistry, Hutton declared the reality of a system in which the Earth had "no vestige of a beginning, — no prospect of an end."[22]



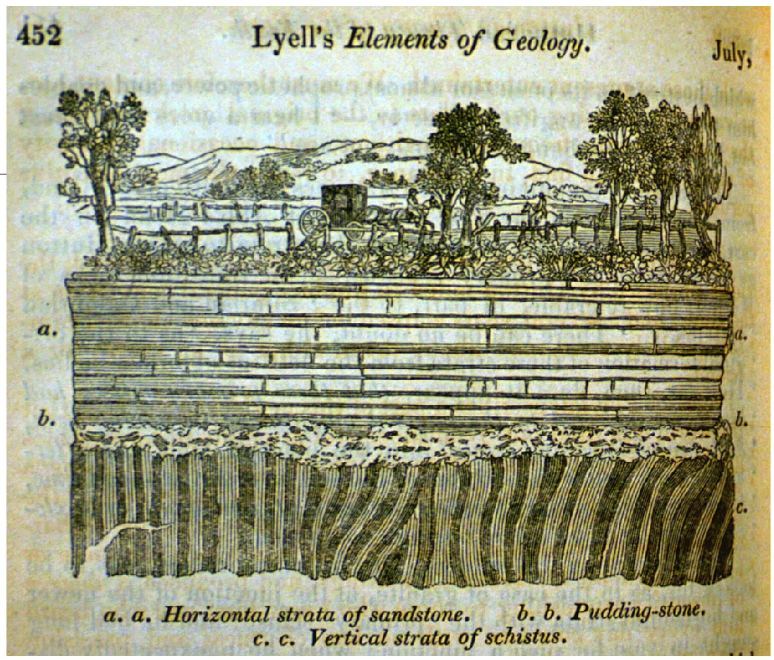


FIGURE 31. John Clerk of Eldin, Jedburgh strata described by Hutton (1795). From Fitton, 1839. Courtesy Bizzell Library, University of Oklahoma.

Explanation. Fitton's lengthy review of Lyell's *Elements of Geology* (1838) appeared in the 1839 volume of the *Edinburgh Review*. The review essay was untitled but as a comparison of the two page headers suggests, Fitton regarded Lyell's work as an extension of the "Huttonian *Theory of the Earth*." Indeed, Fitton chided Lyell for "silent appropriation" and neglect of the "duty of reference," and set out on behalf of his fellow Scotsman "to attempt a rectification of some points in the history of geological theory."[23]

[21] Among others, Stephen Jay Gould has argued that Hutton's fieldwork played a minimal role in the development of his Theory, but this widespread impression has been refuted by David Leveson and Dennis Dean; cf. Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge: Harvard University Press, 1987), David J. Leveson, "What was James Hutton's Methodology?" *Archives of Natural History* 23 (1996): 61–77; and Dennis R. Dean, *James Hutton and the History of Geology* (Ithaca: Cornell University Press, 1992).

[22] James Hutton, "Theory of the Earth; or an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe," *Transactions of the Royal Society of Edinburgh* 1 (1788): 304, reproduced in James Hutton, *James Hutton's System of the Earth, 1785; Theory of the Earth, 1788; Observations on Granite, 1794; together with Playfair's Biography of Hutton*, ed. George W. White, facsimiles of the original editions, vol. 5 of Contributions to the History of Geology (New York: Hafner Press, 1973), 304; hereafter White, *Contributions to the History of Geology*, vol. 5.

Now consider the comments introducing a reprint of Hutton's *System of the Earth* (1785), written in a heroic, inspirational mode by the indefatigable geologist-historian Victor A. Eyles:

> Time was to show, however, that it [Hutton's book] was the most important contribution to the advancement of the natural sciences made in the eighteenth century, for it not only opened the way to the great advances in geology made in the nineteenth century, but the conception of unlimited geological time that it embodied provided a firm basis on which to develop the theory of organic evolution.[24]

With the telling phrase "opened the way" Eyles reveals a triumphalist reading of nineteenth-century developments back into eighteenth-century natural philosophy. Yet "the great advances in geology made in the nineteenth century" cannot be attributed simply to Hutton's influence, nor was Hutton any more a precursor of evolutionary views than Linnaeus, Buffon, Cuvier or Lyell. Directionalist and historical views—the antithesis of Hutton's cyclic and ahistorical Earth system—were more consistent with Darwinian evolution. In writing history backwards here, Eyles was slipping into Whiggish distortions.[25]

To disavow presentism in a such a case is not to dismiss the need for a celebratory justification of present knowledge in a field of modern science. Writing in an inspirational mode may serve legitimate pedagogical ends; indeed, according to Thomas Kuhn the common knowledge of a number of such paradigmatic accomplishments comprises an initiatory rite that in part defines a profession.[26] But celebration need not be uncritical and unhistorical. Nor must one choose between celebrating science as a practitioner and criticizing it from a

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[23] [William Henry Fitton], "Lyell's *Elements of Geology*, Huttonian Theory of the Earth," *Edinburgh Review* 69 (1839): 406–466, quotations on pp. 411 and 406. Cf. Charles Lyell, *Elements of Geology* (London: John Murray, 1838). Hutton described the Jedburgh phenomena (what is now termed an "angular unconformity") in James Hutton, *Theory of the Earth, with Proofs and Illustrations*, 2 vols. (Edinburgh: for Cadell and Davies, London, 1795), 1: 432–440. An engraving of the strata near Jedburgh made from a sketch drawn by John Clerk of Eldin in 1787 was originally published as Plate III in the first volume of Hutton's *Theory of the Earth* (1795); for the provenance of this and other images see Gordon Younger Craig, Donald B. McIntyre and Charles D. Waterston, eds., *James Hutton's Theory of the Earth: The Lost Drawings* (Edinburgh: Scottish Academic Press, 1978).

[24] Introduction by Victor Ambrose Eyles to White, *Contributions to the History of Geology*, vol. 5, xi.

standpoint of alienation, for there is a common need, incumbent upon scientists and historians alike, to avoid alienation from the actor's own categories and historical context. Ironically, important disciplinary ends may be undermined in the long run if presentist distortions prevent an understanding of what historical figures thought they were up to.

More to the point, Hutton was himself a self-confessed Theorist of the Earth and was defended as such by his most influential advocate, John Playfair.[27] Despite overwhelming internal and external attestation, geologist-historians intent on praising the precursor have hailed him as the "founder of geology"[28] and "perhaps the first student of the earth who may properly be called a geologist."[29] Accordingly, in this view Hutton becomes an empiricist untainted by the speculation which allegedly characterized the Theory of the Earth tradition: "James Hutton's *Theory of the Earth*, published in 1795, is the earliest comprehensive treatise which can properly be considered a geological synthesis rather than an imaginative exer-

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[25] On the directionalism of Hutton's contemporaries see Reijer Hooykaas, *Natural Law and Divine Miracle: A Historical-Critical Study of the Principle of Uniformity in Geology, Biology and Theology* (Leiden: E. J. Brill, 1959; reprinted with new Preface as *The Principle of Uniformity in Geology, Biology and Theology*, Leiden: E. J. Brill, 1963), 93–95, hereafter Hooykaas, *Principle of Uniformity*; and Martin J. S. Rudwick, "Uniformity and Progression: Reflections on the Structure of Geological Theory in the Age of Lyell," in *Perspectives in the History of Science and Technology*, ed. Duane H. D Roller (Norman: University of Oklahoma Press, 1971), 209–227; hereafter Rudwick, "Uniformity and Progression." On the definitions of temporal terms see Table 2, "Taxonomy of Temporal Sensibilities, or Visions of the Earth's Past," on page 25. Eyles, after noting Hutton's statement that "with respect to human observation, this world has neither a beginning nor an end," remarked that "this historic statement was one of great prescience, considering the time at which it was first made; and time has proved that Hutton was right." Eyles, Introduction, xix. This Whiggish approach reminds one of the comment of Marquis de Laplace: "When we have at length ascertained the true cause of any phenomenon, it is an object of curiosity to look back, and see how near the hypotheses that have been framed to explain it approach towards the truth." Pierre Simon Marquis de LaPlace, *Celestial Mechanics*, trans. Nathaniel Bowditch, 4 vols. (translation originally published as *Mécanique Céleste*, Boston, 1829; reprinted New York: Chelsea Publishing Company, Inc., 1966), 4: 1015–1016; cited by Stephen G. Brush, "Should the History of Science be Rated X?" *Science*, 1974, 183: 1169. Compare the comment of Seneca on the motion of comets, which presages the dull and uninteresting chronicles to be contained in future Whiggish histories: "There will come a time when our descendants will be amazed that we did not know things that are so plain to them." Seneca, *Natural Questions* VII.25.6; Lucius Annaeus Seneca, *Naturales Quaestiones*, trans. Thomas H. Corcoran, vol. 2, Loeb Classical Library, no. 457 (Cambridge: Harvard University Press; London: Heinemann, 1972), 279.

[26] Cf. Thomas S. Kuhn, *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, 1977), 229; and Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2d ed. (Chicago: University of Chicago Press, 1970).

[27] The opening paragraph of the advertisement to Playfair's book explains: "The Treatise here offered to the Public, was drawn up with a view of explaining Dr Hutton's Theory of the Earth in a manner more popular and perspicuous than is done in his own writings. The obscurity of these has been often complained of; and thence, no doubt, it has arisen, that so little attention has been paid to the ingenious and original speculations which they contain." Cf. John Playfair, *Illustrations of the Huttonian Theory of the Earth* (Edinburgh: for Cadell and Davies, London, and William Creech, Edinburgh, 1802), iii; emphasis added.

cise."[30] Geikie characterized Theories of the Earth as fantastic conjectures and unwarranted hypotheses based upon *a priori* speculation, in contrast to Hutton's unbiased observations and careful fact-collecting:

> Hutton's conceptions entirely differed from those of the older cosmologists, who thought themselves bound to begin by explaining the origin of things, and who proceeded on a foundation of hypothesis to erect a more or less *fantastic edifice of mere speculation*.... Instead of invoking conjecture and hypothesis, he proceeded from the very outset to *collect the actual facts*, and to marshal these in such a way as to make them tell their own story. Unlike Werner, *he had no preconceived theory* about the origin of rocks, with which all the phenomena of nature had to be made to agree. His theory grew so naturally out of his observations that it involved *no speculation* in regard to a large part of its subject.[31]

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[28] Archibald Geikie christened Hutton as the "Founder of Modern Geology," and the phrase—now etched on his gravestone in Edinburgh—was soon echoed by E. B. Bailey; Dean, *James Hutton*, 1; and Edward Battersby Bailey, *James Hutton—The Founder of Modern Geology* (Amsterdam: Elsevier Publishing Company, Ltd., 1967). Geikie also referred to Hutton as the "father of Modern Geology" in the preface to the first publication of the third volume of Hutton's *Theory of the Earth*; James Hutton, *Theory of the Earth, with Proofs and Illustrations*, ed. Archibald Geikie, vol. 3 (London: Geological Society, 1899), xv. Adams referred to Hutton more modestly as "one of the founders of modern geology," though he selected a portrait of Hutton to use as the frontispiece of his survey of geological science; Frank Dawson Adams, *The Birth and Development of the Geological Sciences* (Williams & Wilkins, 1938; reprinted New York: Dover, 1954), 239; hereafter Adams, *Birth and Development*. White summarizes the textbook view of Hutton: "James Hutton, regarded as the founder of modern geology, recognized the length of geologic time, the uniformity of geologic processes in time, and the role of igneous activity, sedimentation, and erosion in forming the earth as we know it." White, *Contributions to the History of Geology*, vol. 5, ix. In a review of Dean, David Oldroyd provides a mitigated endorsement of Hutton as the founder of geology; David R. Oldroyd, "James Hutton, The Founder of Modern Geology?" *British Journal for the History of Science* 27 (1994): 213–219.

[29] Charles Coulston Gillispie, *The Edge of Objectivity: An Essay in the History of Scientific Ideas* (Princeton: Princeton University Press, 1960), 293.

[30] Charles Coulston Gillispie, *Genesis and Geology: A Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790–1850* (Cambridge: Harvard University Press, 1951), 41. Cf. Eyles, in White, *Contributions to the History of Geology*, vol. 5, xiv: "...Hutton's Theory was far from being an academic exercise, conceived in his study, as were most eighteenth century theories. It was primarily based on a long and critical study of rocks in the field." Dampier's sudden shift from literal description to mixed metaphor is somewhat incongruous: "For fourteen years he pondered over the familiar ditches, pits and river beds, and then, returning to Edinburgh, laid the foundations of the modern science of geology." Sir William Cecil Dampier, *A History of Science and Its Relations with Philosophy and Religion*, 4th ed. (Cambridge: Cambridge University Press, 1948), 270–271. Adams similarly extolled Hutton's inductivism (invoking a biblical allusion favored by Bacon): "Hutton himself, on the other hand [in contrast to Werner], had travelled rather widely and his followers had studied the geology of almost every country in Europe and some of those in other continents, and found the confirmation of the Plutonic Theory written in the records of the rocks. The prophecy of Daniel was being fulfilled: 'Many shall run to and fro and knowledge shall be increased.'" Adams, *Birth and Development*, 246.

[31] Archibald, Sir Geikie, *The Founders of Geology*, 2d ed. (London: Macmillan and Company, 1905; reprinted New York: Dover, 1962), 167; italics added. Cf. page 51 on disjunctive rhetorical maneuvers. Contrast William Phillips' description of Werner as a theorist in footnote 103 on page 56, and Playfair's praise for Hutton's *speculations* in footnote 27 on page 276.

Historians such as Dennis Dean continue to repeat the refrain, tirelessly echoing the observation vs. speculation polarity with an analogous dichotomy between facts and theories: "Hutton, Playfair tells us, could rarely be persuaded to read the geological theories of other authors, but he was an avid consumer of geological facts, which he sought out industriously by reading as many books of travel and description as he could find."[32]

In contrast to these Whiggish assessments, recent historians of science have de-emphasized the significance of Hutton for the development of nineteenth-century historical geology. Hooykaas and Rudwick have shown that Hutton was far from unique in explaining geological phenomena by reference to actual processes, rather than postulating unknown causes or invoking supernatural agency. Mott Greene has shown that innovative and productive geological research programs on which Huttonian Theory had little effect were avidly pursued outside Britain. Rachel Laudan has described the dominant framework of early nineteenth-century historical geology as a "Wernerian radiation" driven by the historical turn implicit in Werner's time-based definition of "formation," whose numerous exponents broke new ground not exploited by the cyclical Huttonian "System of the Earth." So the heroic British succession from Hutton to Lyell to Darwin has been challenged by a more-directionalist-than-uniformitarian, more-continental-than-British storyline.[33]

The significance for Hutton's Theory of his deistic teleology, his agricultural vocation, his non-Baconian hypothetical methodology, and the Black-Boerhaavian philosophy of heat and solar matter underlying his account of consolidation has been excavated by a number of scholars, firmly placing him in a decidedly eighteenth-century milieu. Cultural historians have noted Hutton's debt to certain strands of the Scottish Enlightenment, touching on develop-

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[32] Dean, *James Hutton*, 13. Compare Playfair's contrasting interpretation of the relationship between facts and theories quoted above, page 53.

[33] Hooykaas, *Principle of Uniformity*; Rudwick, "Uniformity and Progression"; Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World*, Cornell History of Science Series (Ithaca: Cornell University Press, 1982); Rachel Laudan, *From Mineralogy to Geology: The Foundations of the Earth Sciences, 1660–1830*, Science and Its Conceptual Foundations, ed. David L. Hull (Chicago: University of Chicago Press, 1987).

ments in chemistry and the British empiricist philosophical tradition to which Hutton was closely related.[34] In summary, Roy Porter accurately situated Hutton's affinity to the Theories of the Earth tradition:

> For, if we were to say that the science of the Geological Society of London became the *locus classicus* of contemporary geology, then geology in that sense was little practised in Scotland. Hutton himself did not often use the term. Jameson rejected it in favour of Wernerian 'geognosy.' In some ways, indeed, Scotland at the turn of the century witnessed the last stand of the old traditions of cosmogonical theory and of the natural history of the earth.[35]

Overall, then, one must conclude that Whiggish interpretations praising Hutton as a precursor in the historiography of geology have obscured more of Hutton's own world than they have illumined, thereby diminishing prospects for a full understanding of his accomplishments.[36] Moreover, by transplanting selected later Theorists into the domain of geology, such interpretations obscure for modern historians the very interesting processes of transformation which occurred as the Theories of the Earth textual tradition graded into the emerging nineteenth-century technical geoscience disciplines, just as the selective rhetoric of early geologists obscured the importance of Theories of the Earth for their own endeavors. Thus have Whig-

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[34] See the sources listed in footnote 20 on page 273 and Arthur L. Donovan, "James Hutton and the Scottish Enlightenment—Some Preliminary Considerations," *Scotia* 1 (1977): 56–68; James Hutton, *James Hutton's medical dissertation*, ed. Arthur L. Donovan and Joseph Prentiss (Philadelphia: American Philosophical Society, 1980); François Ellenberger, "Les Origines de la Pensée Huttonienne: Hutton étudiant et Docteur en Médicine," *Comptes Rendus Hebdomadaire des Séances de l'Académie des Sciences* 275 (1972): 69–72; R. Grant, "Hutton's theory of the earth," in *Images of the Earth: Essays in the History of the Environmental Sciences*, ed. Ludmilla J. Jordanova and Roy S. Porter, BSHS Monographs, no. 1 (Chalfont St. Gilles, England: British Society for the History of Science, 1978), 23–38; P. M. Heimann, "'Nature is a Perpetual Worker': Newton's Aether and Eighteenth-Century Natural Philosophy," *Ambix* 20 (1973): 1–25; P. M. Heimann and J. E. McGuire, "Newtonian Forces and Lockean Powers: Concepts of Matter in Eighteenth-Century Thought," *Historical Studies in the Physical Sciences* 3 (1971): 233–306; Peter Jones, "An Outline of the Philosophy of James Hutton," in *Philosophers of the Scottish Enlightenment*, ed. V. Hope, 182–210 (Edinburgh: The University Press, 1984); J. E. O'Rourke, "A Comparison of James Hutton's *Principles of Knowledge* and *Theory of the Earth*," *Isis* 69 (1978): 5–20; Jean Jones, "James Hutton's Agricultural Research and his Life as a Farmer," *Annals of Science* 42 (1985): 573–601; and Douglas Allchin, "James Hutton and Phlogiston," *Annals of Science* 51 (1994): 615–635.

[35] Roy S. Porter, *The Making of Geology: Earth Science in Britain, 1660–1815* (Cambridge: Cambridge University Press, 1977), 149–150.

[36] Nevertheless, excellent overviews of Hutton's work are found in Rachel Laudan, *From Mineralogy to Geology: The Foundations of the Earth Sciences, 1660–1830*, Science and Its Conceptual Foundations, ed. David L. Hull (Chicago: University of Chicago Press, 1987), and Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology*, 2d ed. (London: Macdonald, and New York: American Elsevier, 1972; Chicago: University of Chicago Press, 1976).

gish dichotomies contributed to the construction of caricatures of both Theories of the Earth and the disciplinary origins of geology.

§ 3. Lyell and Histories of Scientific Disciplines

The converse tendency to "praising the precursor," equally Whiggish, is "blaming the backward." Whiggish historians not only mischaracterize the superficially similar, but also tend to regard past figures whose knowledge or methods differed from present views as obstructive hindrances to progress. This tendency is pronounced in longitudinal histories of scientific disciplines, for a number of reasons, many of which become clear when one contemplates the different roles historical accounts play within science. One recent taxonomy helpfully illustrates the variety of scientific uses of history, describing six different roles.[37] The first four modes of "science history" (above the double line in Table 34) are typically written by scientists, for scientists, or for the sake of science, while the last two forms of "history of science" (below the double line in Table 34) are typically written by historians and for historians.[38] Using Hutton as an example, samples of the first three types of science history were introduced in the previous section. Analytic history is illustrated by Rachel Laudan's revisionist view of the relative significance of Werner and Hutton, or by the analysis of textual and technical traditions in Chapter 1. Interpretative history is illustrated by the contextual studies of Arthur Donovan and other works cited above, or by the present interpretation of the importance of hexameral idiom for the development of historical sensibilities in Theories of the

[37] Harry Collins and Trevor Pinch, *The Golem: What You Should Know about Science,* 2d ed. (Cambridge: Cambridge University Press, 1998), pp. 160-161, 165-167. A relevant discussion distinguishing four levels of science literature (specialized expert, general expert, textbook, and popular) is found in Ludwik Fleck, *Genesis and Development of a Scientific Fact,* trans. Fred Bradley and Thaddeus J. Trenn, ed. Thaddeus J. Trenn and Robert K. Merton, foreword by Thomas S. Kuhn (Chicago: University of Chicago Press, 1979), 111–125. For a helpful extended analysis of contrasts between textbook science, review literature, and frontier science, see Henry H. Bauer, *Scientific Literacy and the Myth of the Scientific Method* (Urbana: University of Illinois Press, 1992).

[38] Something like this characterization of "science-history" and "history of science" was proposed by Alan G. Debus, "The Relationship of Science-History to the History of Science," *Journal of Chemical Education* 48 (1971): 804–805.

Earth. The remainder of this section explores the character of official and reflective forms of science history.

TABLE 34. **Types of History of Science, Collins and Pinch**[a]

Mode	Description	Hutton Example
Textbook history	Simplified, pocket-size versions of current beliefs dressed up in historical guise. Whiggish, often mythical. **Aims:** to make science easier to learn; to add human interest; to reinforce methodological morals.	"Hutton, the founder of geology" (see previous section)
Review history	**Written by:** leading frontier scientists. **Aim:** to sort out current state of a field and establish a basis for new work, such that the review counts as a scientific publication in its own right.	William Henry Fitton, "The Huttonian Theory of the Earth" (see previous section)
Official history	**Written by:** respected senior scientists, adopting a heroic or inspirational mode; often Whiggish. **Aims:** to properly distribute credit; to sort out lineages of established current views.	
Reflective history	**Written by:** scientists, perhaps as memoirs, and by rational reconstructionist philosophers. **Aim:** to improve the methods and conduct of science, strongly demarcating good science from poor science or pseudoscience, emphasizing the success of particular approaches.	The historical survey in the first volume of Lyell, Principles of Geology, 1830
Analytic history	**Written by:** historians, sociologists, empirically-minded philosophers or practitioners. **Aims:** To understand "the nature of science" as it is actually practiced, rejecting (like Interpretative history) rationalist reconstructions characteristic of the previous four types. Also attends to successful false theories; e.g. Paracelsian chemistry, Proutian atomic theory, wave theories of light before 1820, Theories of the Earth, etc.	Rachel Laudan, Emergence of Geology as a Discipline (Chicago, 1984)
Interpretative history	**Written by:** historians and others. **Aims:** To reconstruct lost human worlds, or the world as it was perceived by the actors themselves, of understanding past natural knowledge in its local and cultural contexts without anachronisms (and without necessarily endorsing general philosophical or sociological theses regarding the "nature of science"); to explain interplay of contingent factors in historical development.	Donovan's studies of Hutton and other works cited in footnote 34 on page 279

a. Adapted from Harry M. Collins and Trevor Pinch, The Golem: What You Should Know about Science and Technology (Cambridge, 1998).

A great deal of positivism is latent in disciplinary histories written in the first four modes.[39] To consider the case of reflective history, in a classic article analyzing problems encountered by the use of non-positivist historical studies in scientific instruction Stephen G. Brush alerted scientists to "the advice of J. J. C. Smart, who recently suggested that it is legitimate to use *fictionalized* history of science to illustrate one's pronouncements on scientific method."[40] Not surprisingly, if asked to reconstruct a "fictional history" for the development of natural knowledge of the Earth following the most intelligible or logical paths of discovery on the road to modern geology, few geologists would feel the need, had they never existed, to invent Theories of the Earth nor, once discovered, to rescue them from antiquarian oblivion.[41] They represent a tradition which several generations of geologists have regarded as being, even in its own day, a regressive force and a reactionary obstacle to the emergence of historical geology.

It is readily apparent why the presentist tendency to "blame the backward" would be associated with positivist assumptions inherent in disciplinary histories. For practitioners who approach the history of science as a cumulative chronicle of the linear development of a current scientific discipline, Theories of the Earth understandably hold little interest, often displaying utter ignorance of fundamental facts now familiar to any beginning student (e.g., the rock cycle, the utility of index fossils, the role of plate tectonics in mountain building and the relative youth of ocean basins). In this case the role of Theories of the Earth reduces to that of

[39] On positivism, see "Theories and Facts," beginning on page 52.

[40] J. J. C. Smart, "Science, History and Methodology," *British Journal for the Philosophy of Science* 23 (1972): 266–274; cited in Stephen G. Brush, "Should the History of Science be Rated X?" *Science* 183 (1974): 1170. Smart argued (p. 268) that "fictitious examples [of the history of science] are as good as factual ones," and "Methodologists need examples from the history of science only because it is too hard to think up fictitious ones. It does not matter, therefore, whether the history is quite true." Careless readers of Brush's article sometimes overlook the fact that in his conclusion Brush did not agree with Smart's suggestion.

[41] I tried to make a similar point by comparing Theories of the Earth with the Cambrian period in footnote 7 on page 10. On the progression of science compare the opening quotation from Gould on page 6 and my paraphrase on page 11.

blame; in the converse of the celebratory mode, their only pedagogical utility appears to be negative reinforcement as anti-paradigms and anti-heroes.

An example of presentist disciplinary history is John Challinor's published list of British works contributing to the progress of geology. While Challinor acknowledged that his list is selective, he expressed hope "that no work of importance has been left out."[42] Consistent with the aims of an "Official history," British Theories of the Earth such as Thomas Burnet's and William Whiston's were omitted, as he explained:

> In a general history of geology it would obviously be important to enumerate and discuss the various successive ideas and controversies, in all countries, as to how the earth has come to be as we now know it, both as to its outer features and its inner structure. This is outside our province, which is the growth of *sound knowledge* about the geology of Britain."[43]

When on occasion a Theory of the Earth is included, such as John Whitehurst's, John Woodward's, or James Hutton's, Challinor "praises the precursor" by attempting to dissociate the "sound knowledge" it might contain from the tradition as a whole:

> Imaginary and unnatural theories as to the formation and subsequent history of the earth were rife and voluminous from the latter part of the seventeenth to the latter part of the eighteenth centuries. John Whitehurst's 'inquiry,' 1778 into these matters is as practically worthless as any of the others but, as in the case of John Woodward, his book contains very valuable material. His 'observations on the strata in Derbyshire' really constitute a quite separate treatise which is one of the main landmarks in the progress of knowledge in British geology, being packed with significant facts and just inferences. He enunciates the principle of the orderly superposition of strata, describing the succession of the Carboniferous rocks of Derbyshire; and he discusses the character of the fossils as affording evidence of marine or freshwater deposition.[44]

Here Challinor's work displays the concern for strong demarcation characteristic of "Reflective history." Yet when a disciplinary historian inclined to blame the backward and praise the

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[42] John Challinor, *The History of British Geology: A Bibliographical Study* (New York: Barnes & Noble, 1971), 9; hereafter Challinor.

[43] Challinor, 83; italics added. This comment was made as part of his Theme 18 (of 86) entitled "Speculation during the seventeenth and eighteenth centuries."

[44] Challinor, 64-65. Whitehurst's Theory is discussed in "Whitehurst's Enigma," beginning on page 668.

precursor discovers that they are one and the same, the result is rather schizophrenic. It is as if Whitehurst and Woodward each wrote two books, one a worthless Theory of the Earth best forgotten and discarded, and the other a contribution to sound knowledge in the history of geology provided one can abstract it sufficiently from the form in which it was originally presented.[45]

Challinor's characterization of Theories of the Earth seems almost charitable, however, compared with other histories of geology. Speaking of Thomas Burnet, Buffon, and other pre-Wernerian Theories of the Earth, the best-selling history of geology by Frank Dawson Adams stoops to the level of "Textbook history" when it recommends that:

> These early fables of geological science should be read by all who are in need of mental recreation and who possess the required leisure and a certain sense of humor, although many of them make a further demand upon the seeker after amusement and recreation in this fairyland of science, namely, that he shall have to seek this relaxation in the somewhat unaccustomed field of medieval Latin.[46]

This unflattering attitude is also obvious in Archibald Geikie's earlier but equally-influential "Official history":

> The chief obstructors of progress were the cosmogonists who, often with the slenderest equipment of knowledge of nature, endeavoured to account for the origin of things. They were not disconcerted by phenomena that contradicted their theories, for they usually never saw such phenomena, and when they did, they easily explained them away.[47]

In this typical Whiggish assessment of Theories of the Earth, Geikie echoed Charles Lyell, the great nineteenth-century geologist whose three-volume *Principles of Geology* (1830–1833) began with a 90-page "Reflective history" of geology. From Lyell's survey, it is probably fair to say, most English-speaking geologists since Lyell have directly or indirectly derived their views

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[45] Compare the parallel treatment of Kepler and Newton noted above (page 270).

[46] Adams, *Birth and Development*, 210.

[47] Archibald Geikie, *The Founders of Geology*, 2d ed. (London: Macmillan and Company, 1897; reprinted London: Macmillan and Company, 1905; reprinted New York: Dover, 1962), 6–7. Cf. David R. Oldroyd, "Sir Archibald Geikie (1835–1924), Geologist, Romantic Aesthete, and Historian of Geology: The Problem of Whig Historiography of Science," *Annals of Science* 37 (1980): 441–462.

of the early history of geology and of Theories of the Earth, receiving in addition generous doses of presentist methodology and demarcationist rhetoric.[48]

Lyell's discourse was no mere historical chronicle, as Martin Rudwick has pointed out, but a cleverly-devised polemical strategy to establish his own anti-directionalist theoretical views.[49] As such, it contained severe distortions and mischaracterizations of past views, covertly targeted against contemporary geologists who were themselves directionalists like many Theorists of the Earth. Lyell specialized not only in rational reconstructions of his favored views, but in "irrational reconstructions" of the predecessors esteemed by those who disagreed with his geological methods. As Lyell put it:

> It may be well to forewarn our readers, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, they must expect to be occupied with accounts of the retardation, as well as of the advancement of the science. It will be our irksome task to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions. It will be necessary to dwell on futile reasoning and visionary hypothesis, because the most extravagant systems were often invented or controverted by men of acknowledged talent. A sketch of the progress of Geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to one who studies the philos-

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48 Charles Lyell, *Principles of Geology*, 3 vols. (London: J. Murray, 1830–1833; facsimile reprint Chicago: University of Chicago Press, 1991). Hereafter, "Lyell, *Principles*."

49 In the exposition of an anti-directionalist theory of climate occurring midway through the first volume of Lyell's *Principles*, strategically placed immediately after the anti-directionalist historical survey, Lyell waxed eloquent on the grandeur of a cyclic pattern of life, with purple prose conveying his utter opposition to a directionalist view: "We might expect, therefore, in the summer of the 'great year,' which we are now considering, that there would be a great predominance of tree-ferns and plants allied to palms and arborescent grasses in the isles of the wide ocean, while the dicotyledonous plants and other forms now most common in temperate regions would almost disappear from the earth. Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyle might flit again through umbrageous groves of tree-ferns...." On Lyell's theory of climate see Dov Ospovat, "Lyell's theory of climate," *Journal of the History of Biology* 10 (1977): 317–339. For the structure of Lyell's argument in the *Principles* and the strategic use of the historical opening see Martin J. S. Rudwick, "Introduction" to *Principles of Geology*, by Charles Lyell, vol. 1 (Chicago: University of Chicago Press, 1990), vii–lviii. For a description of the "directionalist" sensibility of geologists in Lyell's day, see Martin J. S. Rudwick, "Uniformity and Progression: Reflections on the Structure of Geological Theory in the Age of Lyell," in Duane H. D. Roller, ed., *Perspectives in the History of Science and Technology* (Norman: University of Oklahoma Press, 1971), 209-227, and the response by Rhoda Rappaport, "Commentary on the Paper of M. J. S. Rudwick," 228–231. Such directionalism underlies Henry Thomas De la Beche's often-reprinted caricature of the just-quoted Ichthyosaur passage of Lyell, analyzed in Martin J. S. Rudwick, "Caricature as a Source for the History of Science: De la Beche's anti-Lyellian Sketches of 1831," *Isis* 66 (1975): 534–560; cf. footnote 104 on page 56 above.

> ophy of the human mind, is singularly barren of instruction to him who searches for truths in physical science.[50]

In Lyell's disciplinary historiography, an acme of "blaming the backward" presentism, there is no excuse for error. Given his claims for the efficacy of proper methodology, those who have searched for scientific truth and failed in the attempt bear the shame of their own culpability. Those who would study a natural science need not seek physical truth from history, since the only tales a disciplinary history could possibly add to the present stock of knowledge are accounts of fruitless and false beliefs, at one time accepted with inadequate warrant but since rejected and discarded.[51] Lyell's principles of the history of geology were as ahistorical as his principles of geology.[52]

Misunderstandings regarding presentism have been multiple and contentious so further clarifications are necessarily, particularly in light of contemporary controversies over the value of "Science Studies."[53] In *The Two Cultures,* C. P. Snow drew attention to a rift in communication and a chasm of mutual incomprehension between scientists and nonscientists. There have always been many divides in academia; Snow's "two cultures" are not the only ones who tend to speak past one another.[54] Nearly forty years after Snow popularized the idea of the two cultures (dispensing a generous dose of scientism for added measure), assorted science-

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[50] Lyell, *Principles of Geology*, 1: 30; emphasis added.

[51] On Pallas' contrasting view of the heuristic utility of his own Theory, see above, page 268. Defenses of the possible utility of history of science for science (and vice-versa) include Stephen G. Brush, "Scientists as Historians," *Osiris* 10 (1995): 215–231; and Philip Kitcher, "A Plea for Science Studies," in *A House Built on Sand: Exposing Postmodernist Myths About Science*, ed. Noretta Koertge (Oxford: Oxford University Press, 1998), 32–56.

[52] On Lyell's historiography see Paul J. McCartney, "Charles Lyell and G. B. Brocchi: A Study in Comparative Historiography," *British Journal for the History of Science* 9 (1976): 175–189; Roy S. Porter, "Charles Lyell and the Principles of the History of Geology," *British Journal for the History of Science* 9 (1976): 91–103; Martin J. S. Rudwick, "Historical Analogies in the Geological Work of Charles Lyell," *Janus* 64 (1977): 89–107; and Rachel Laudan, "Redefinitions of a Discipine: Histories of Geology and Geological History," in *Functions and Uses of Discipinary Histories*, ed. Loren Graham, vol. 8 (Dordrecht: D. Reidel, 1983), 79–104.

[53] Some of the material in the following paragraphs, including Table 35, Table 36, and Table 37, are adapted from a set of web pages entitled "What are Science Studies?" which provide further commentary and documentation; *cf.* Kerry Magruder, *http://www.earthvisions.net/hsci/scienceStudies/index.html*. The book by Collins and Pinch cited in footnote 37 has become a central text in the so-called "Science Wars" controversy.

[54] Shortly thereafter, in "The Two Cultures: A Second Look," Snow made it three cultures instead of two by adding the social sciences.

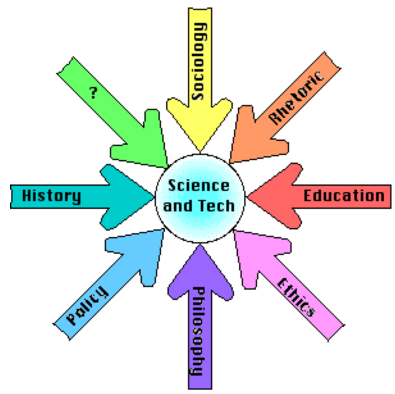
centric endeavors collectively known as Science Studies have come to maturity.[55] Although in principle Science Studies offer an opportunity to transcend Snow's "Two Cultures," controversies over Science Studies seem to have intensified rather than alleviated the misunderstandings and miscommunications. Little consensus exists among scientists and the various practitioners of Science Studies regarding what the latter should be or do. Most views seem to reflect one of two scientific cultures, summarized in the model diagrams shown in the two following tables.

- Each culture is centered upon science and technology as its **general subject matter**, as suggested in the diagrams by the central area occupied by "Science and Technology."
- **Various professions**, each with its own autonomous area of expertise, contribute to the interdisciplinary endeavor known as Science Studies. Such professions are represented by various arrows.[56]
- However, each culture maintains its own set of expectations about Science Studies, particularly regarding whether a **primary aim** of Science Studies should be utility for scientists or whether practitioners publish primarily for a different or broader audience. In the diagrams the primary aim is represented by the direction of the arrows: either Centri**petal (Table 35)**, seeking the center; or Centri**fugal (Table 36)**, fleeing the center.

[55] Science Studies and "STS" or "Science, Technology and Society" have largely replaced the earlier "HPS," or "History and Philosophy of Science." The latter was a marriage of convenience and, professionally speaking, the partners now live separately. For one representative account of these developments see Kevin T. Grau, "Force and Nature: The Department of the History and Philosophy of Science at Indiana University, 1960–1998," in *Catching Up with the Vision: Essays on the Occasion of the 75th Anniversary of the Founding of the History of Science Society*, ed. Margaret Rossiter (A Supplement to *Isis*, Volume 90, published by the University of Chicago Press for the History of Science Society, 1999), 295–320.

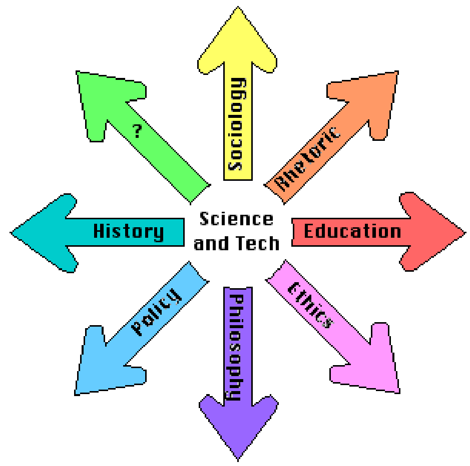
[56] In the present context the focus is upon history of science only, and specifically upon the history of geology; for a documented and more general discussion of various Science Studies professions see the web pages cited in footnote 53.

TABLE 35. **Science-Centripetal Culture of Science Studies**

Science Studies model	Examples of major topics and approaches
Science-Centripetal Culture: **Science Studies justified by their utility for scientists** **Primary aim:** To help scientists do better science, and to help citizens provide better support for scientists. **Primary audience:** scientists, science educators, and science-affected citizens.	 Science-centripetal culture
Science History (cf. the first four types in Table 34)	•**Internalist:** development of theory content, discoveries, instruments, abstracted from cultural, social, and local contexts. •Historians as “**insiders**,” publishing for a scientific audience as much as for other historians, often in **disciplinary** histories in the form of textbooks, reviews, and memoirs. •Often **positivist** in orientation, emphasizing the gradual accumulation of sound knowledge. Only cursory attention is paid to false hypotheses and mistaken paths of inquiry, let alone any productive or fruitful consequences arising therefrom. •Often **presentist** or **Whiggish** in orientation, praising the precursor and blaming the backward. Interpretations of past episodes are selected and reconstructed in order to reflect (or contribute to) current problems of disciplinary boundaries, methodology, or content.

The celebratory assessments of Hutton in the disciplinary histories discussed above, indelibly colored by Lyellian presentism, conform to this "science-centripetal" model with its primary aim of utility for scientists. Defenders of presentism often share the disciplinary orientation of Lyell, writing only "to him who searches for truths in physical science" in that they urge the utility of presentist studies for modern practitioners or for inculcating a common identity among students of the discipline based on an alleged similarity of past theories, problems, practices, or methods to current ones. In contrast, scholarship that criticizes the distortions of presentist accounts may appear (whether intentionally or not) to undermine science itself, or at least the integrity of the discipline. For example, some geologists have responded to revisionist views of Hutton as if they were personal attacks upon the character of Hutton himself, the national heritage of British geology, or the discipline of geology more broadly. Yet in view of the demonstrated limitations, prejudices, and errors of "science-centripetal" studies, should historians conclude that disciplinary histories by nature are necessarily flawed? Should historians shun any attempt to make their historical accounts relevant to, or worth reading by, scientists? Such a reaction represents the formation of a "science-centrifugal" culture, summarized in Table 36.

TABLE 36. **Science-Centrifugal Culture of Science Studies**

Science Studies model	Examples of major topics and approaches
Science-Centrifugal Culture: **Science Studies characterized by little (or even negative) utility for scientists** **Primary aim:** To understand science and technology as part of the fabric of culture (rejecting Snow's "Two Cultures" and other demarcationist attempts). **Primary audience:** Fellow Science Studies specialists and practitioners of various cultural studies in the humanities.	 Science-centrifugal culture
History of Science (cf. the last two types in Table 34)	**Externalist**: cultural contexts (e.g., metaphysical world-views, institutions, patronage) as prerequisites for discoveries and theoretical paradigm shifts **Constructionist**: cultural shaping of scientific knowledge (rejecting externalist-internalist distinction) **Historicist**: in the attempt to reconstruct former human worlds, attends to discarded theories and unsuccessful lines of investigation as well as "paradigmatic" episodes, without anachronistic references to current science **Local** and **cultural**: highly situated studies undertaken by historians of particular regions and periods with little or no scientific training, and published for other historians rather than for scientists (historians as "outsiders")

The clash between the two science-centric cultures has been popularized (and polarized) in the so-called "Science Wars." Is it possible to move beyond the irreconcilable *status quo* of the two contrasting science-centric cultures, to open channels of communication and understanding that are still largely unexploited and to find common ground without sacrificing the integrity of each discipline's professional aims and expertise? That is the hope embodied in the present argument for a reassessment of Theories of the Earth, which follows the four sets of paired guidelines shown in Table 37. Each set of guidelines together guards against some kind of exclusive authority claimed by one side or another, while also avoiding the reduction of the disciplinary aims of either one to those of the other—maneuvers which manifest the "Two Cultures" ideology that still bedevils communication between professionals in science and science studies.

TABLE 37. Integrated Scientific Culture

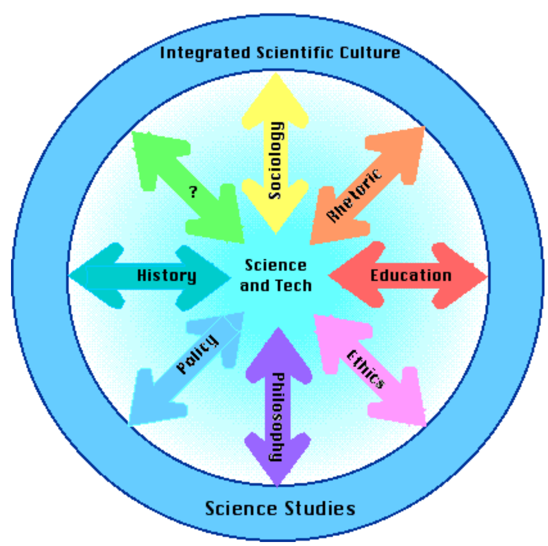
The search for overlapping concerns among Science and Science Studies **Four guidelines**	"The whole is more than the sum of its parts." 
A. Applications for Science Studies Practitioners	**B. Applications for Science Practitioners**
1. Affirm the legitimacy of "Meta-science" rather than insisting upon a dichotomy of "Pro-science" vs. "Anti-science" (reject the attitude "If you're not with me, then you're against me")	
One need not become "anti-science" in order to understand the culture of science in the context of its history, philosophy, or sociology (etc.). Science Studies professionals need not adopt a belligerent stance in order to claim an independent view.	If someone is not avidly "pro-science," that does not necessarily make them an "enemy" of science. Scientists need not be over-suspicious of the alleged corroding effects of Science Studies upon contemporary science.
2. Affirm "Humanistic" Science Pedagogy The first guideline applied to the area of science education suggests the following:	

TABLE 37. Integrated Scientific Culture

Science Studies professionals should not dismiss the celebratory, justificative, and pedagogical needs of practicing scientists, which are as legitimate in science as similar rituals in any profession. Such identity-forming, boundary-drawing, paradigm-constructing practices are constitutive of disciplines, and although they often provide an illuminating focus of study for Science Studies professionals such practices may be held in mutual respect.	Scientists may find ways to meet celebratory and inspirational needs without violating the findings of Science Studies. In other words, whether suspicious of Science Studies or not, scientists cannot live with their heads in the sand as if these studies did not exist. With some effort and refashioning, exploded historical myths may be removed from textbooks and replaced with historically accurate accounts that will bear the needed pedagogical and discipline-forming burden.
3. Affirm Overlapping Competencies	
Remember that scientific competence is **not disqualifying** for Science Studies. Science Studies professionals should not imply that scientists have little sophisticated self-understanding, and necessarily make poor students of science, historians of science, philosophers of science, sociologists of science, etc.	Remember that scientific competence is **not sufficient** for Science Studies. Scientists should recognize that the various professions of science studies have their own standards and competencies. Scientific competence per se does not qualify anyone to investigate the history or sociology (etc.) of a scientific discipline. No less laboriously acquired than scientific training, a historical, philosophical or sociological (etc.) sensibility, along with associated rigorous methods of any science studies discipline, are no less essential. Eager amateurism is naive and counterproductive.
4. Affirm Relative Autonomy	
Remember that scientific competence is **not superfluous** for Science Studies. Science Studies professionals should not assume that nonscientists make better historians, philosophers, or sociologists (etc.) of science because or so long as they remain ignorant of the area of science they are studying. The autonomy of science studies from science is only relative, not absolute.	Remember that scientific competence is **not necessary** for Science Studies. Science studies have an autonomy of their own which cannot be reduced to the needs of science. For example, the historical interaction of neighboring disciplines, scholarly contexts, and textual traditions is much broader than the concerns of a single disciplinary history can encompass. Scientists should realize that the various professions of science studies have their own problematics, questions, and inquiries, which may neither relate to scientific concerns, nor require scientific contributions, nor be susceptible of scientific evaluation to any significant degree.

To the degree that this study situates Hutton, Cuvier, and others as participants in the Theory of the Earth tradition, it also seeks to rehabilitate that tradition as a successful public forum for legitimate debate between diverse technical fields. Therefore it is offered with the hope that no one will read it as demeaning of Hutton, Cuvier, Lyell or geology (Table 36, Guideline #1), but that it might serve as an attempt to move toward an "integrated scientific culture" rather than either the "science-centripetal" or "science-centrifugal" cultures of science studies.

Second, the pedagogical needs of geologists may be achieved without succumbing to presentist or Whiggish distortions (Table 36, Guideline #2). Scientists need not object to the attempt to reconstruct alternative, perhaps long forgotten, human ways of understanding the world—even if this sacrifices some degree of pedagogical utility in teaching science, or requires a rewriting of textbooks stocked with different examples. To understand past contexts even when they differ from that of the modern practitioner is itself a worthy goal. Cultural appreciation of the development of science does not require that it be useful for furthering present knowledge in corresponding areas of current science. To aim exclusively for pedagogical utility as the only justification for science history sacrifices a deep humanistic understanding of the actors in historical context that might provide a richer and ultimately more gratifying sense of disciplinary heritage. For when the canonical portraits of Hutton are eliminated, he should still have a place in geological textbooks (and for the same reasons, other Theorists of the Earth may deserve a better place in textbook histories as well).

By no means do I wish to imply that by nature disciplinary histories of geology are necessarily flawed, and that it is impossible that they should ever take pre-geological traditions into account with historical understanding. Nor am I in any sense suggesting that geologists necessarily make poor historians of geology (Guideline #3, column A), or that nonscientists make better historians of geology if they remain ignorant of current geological practice (Guideline #4, column B). It is understandable that the science-centrifugal culture of Table 36 in part results from attempts to achieve independence and integrity, to move away from the older Whiggish approaches, and to broaden historical inquiry beyond the constraints of disciplinary histories. However, the history of science as a profession unfortunately has severed too many ties with scientific practitioners, as a consequence suffering lost audiences, missed opportunities for scholarly collaboration, and unrealized possibilities for institutional cooperation of mutual benefit. Yet there are some hopeful signs. Much of the best recent scholarship in the history of science has been accomplished by historians with sufficient scientific expertise to substantially replicate the phenomena experienced by the historical actors. Tom Settle famously replicated the inclined plane experiment of Galileo at a time when most historians of science, following Alexandre Koyré, believed that neither Galileo nor anyone else actually could have carried it out.[57] Competent scientific investigations have made possible similar contributions to various fields, and many notable historians received professional training in the sciences.[58] In the history of geology, for example, attempts to recreate their subjects' fieldwork by David Oldroyd and others have enhanced understanding of historical practices and context.[59] Moreover, excellent work in the history of geology has at times been motivated by a significant historical problem which initially occurred to practicing geologists *during* and *as a result of* their professional activities and training.[60]

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[57] Cf. Alexandre Koyré, *Études Galiléennes* (Paris: Hermann, 1939); Alexandre Koyré, *Metaphysics and Measurement* (Cambridge: Harvard University Press, 1968); Thomas Settle, "An Experiment in the History of Science," *Science* 133 (1961): 19–23; and Thomas Settle, "Galileo and Early Experimentation," in *Springs of Scientific Creativity*, ed. R. Aris (Minneapolis: University of Minnesota Press, 1983), 3–20.

[58] To take the example of chemistry, Larry Principe is a member of the chemistry faculty at Johns Hopkins University, yet his study of Boyle is revolutionizing not only Boyle studies but wider discussions of seventeenth-century mechanical philosophy. Cf. Lawrence M. Principe, *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton: Princeton University Press, 1998). The alchemical studies of William Newman and the studies of Lavoisier and Hans Krebs by Arthur Holmes are just two other examples which suggest that recent progress in historical understanding would have been impossible without some degree of chemical expertise on the part of historians to reconstruct the laboratory circumstances underlying various texts. Contributions by historians trained in physics are abundantly familiar; for examples one need only mention the names of Pierre Duhem and Thomas Kuhn. Similarly, Norton Wise, who holds a doctorate in physics, has coauthored the standard biography of Lord Kelvin with a work that is contextual as well as technical; cf. Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989). See also the articles by Brush and Kitcher cited in footnote 51 on page 286.

[59] David R. Oldroyd, *The Highlands Controversy: Constructing Geological Knowledge through Fieldwork in Nineteenth-Century Britain* (Chicago: Chicago University Press, 1990).

On the other hand, competence in the geosciences does not immediately qualify one to investigate the history of geology (Table 36, Guideline #3, column B). Although no less laboriously acquired, a historical sensibility is no less essential, lest the resulting account slip into a rational reconstruction, a fictional account fashioned exclusively for justifying current knowledge, celebrating the discipline, or indoctrinating beginning students. The various disciplines, aims, theories, methodologies, and practices of modern geology are contingent products of modern history and not essential features of human conduct. Their origin and development is one of the provinces of the historian, although other historical investigations may hold even less interest to practicing geologists, including accounts of once-neighboring disciplines (e.g., meteorology, antiquarianism, classical history and philology, each of whose disciplinary practices were once regarded as the most competent means of investigating subject matter now assigned to geology; cf. Table 36, Guideline #4, column B). The previously alluded to cases of Kepler and Newton illustrate the hazards both of a narrow disciplinary focus, which excludes adequate attention to broader cultural horizons, and of the presentism so often associated with disciplinary aims. In such cases disciplinary histories are as difficult as tracing a single strand throughout a thick and twisted rope where the rope is much longer than the single strand. Presentist endeavors yield abstractions and chimeras rather than accurate, holistic understandings of the actual events, persons, and accomplishments which are named.

An additional caveat is that although Interpretative historical accounts of geoscience and other disciplines (Table 34, number 6) may provide scientists with some measure both of enjoyment and wisdom, they ordain no legislation for the present conduct of geology. Apart

[60] Rudwick briefly reminisces on his initial reading of Cuvier while he was still a paleontologist in Martin J. S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), xii; Oreskes recounts how “the seeds of an intellectual inquiry were sown” during her undergraduate studies in geology; Naomi Oreskes, *The Rejection of Continental Drift: Theory and Method in American Earth Science* (Oxford: Oxford University Press, 1999), vii. The fruitfulness of sustaining interaction between “insiders” and “outsiders” was the theme of a Penrose Conference sponsored by the Geological Society of America on “Interdisciplinary Perspectives on the History of the Earth Sciences” (March 18 - 22, 1994 in San Diego).

from momentarily switching hats with scientists and philosophers, historians *qua* historians do not dictate truths or methodologies or epistemic norms, however much their considered investigations may throw light upon discussions of such matters. In the final analysis, by discovering former human worlds, historians offer scientists and philosophers a humanistic understanding which, without preempting the prerogatives of scientists themselves, may yet enrich their conceptualizations of their own disciplinary identities.

§ 4. Whiston and Pseudoscience

While the distortions of presentism are especially common in disciplinary histories, they are even more likely to occur when a disciplinary history is extended back to times and places where different mental maps shaped the cognitive terrain, before a given discipline existed in anything like its modern form. Thorny questions arise with any investigation into disciplinary origins, reformations, or multi-disciplinary interactions; e.g., the questions of particularly when and where did astrology become astronomy or alchemy become chemistry are irreparably flawed and unanswerable. But the ordinary problems are compounded still further because Theories of the Earth were not the predecessors of any single mainstream present-day intellectual tradition, nor were they coextensive with any modern scientific discipline, geological or otherwise.[61]

Mary Jo Nye described the positivist aim of disciplinary histories as tending "to provide pictures of the cumulative advance of an individual science through a continuous chain of right thinking and observation generally devoid of confusion, false paths, and misassump-

[61] On the interdisciplinary scope and multi-contextual mobility of Theories of the Earth as a textual tradition see "Theories and Disciplines," beginning on page 45. It is interesting that a current series of disciplinary histories has found a way to include Theories of the Earth, along with geology, ecology, and geography, in Peter J. Bowler, *Norton History of Environmental Sciences*, Norton History of Science Series, ed. Roy Porter (New York: W. W. Norton and Company, 1993). In this partition of disciplines Bowler in part follows the lead of Clarence J. Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley: University of California Press, 1967). Yet it is arguable that the disciplinary orientation continues to obscure the recognition of Theories of the Earth as a multi-disciplinary textual tradition.

tions."[62] Like "pseudosciences" such as astrology, alchemy, or spiritualism; like fallacious scientific episodes such as Martian canals, N-rays or Polywater; and like fraudulent scientific examples such as Piltdown Man or the biomedical papers of John Darsee, Theories of the Earth are ignored whenever possible except on polemical or pedagogical occasions when there is need to warn, by historical illustration, of the consequences of neglecting sound (generally positivist) scientific method. When Theories of the Earth cannot be ignored, their antiquated and apparently obsolete character renders them subject to ill regard and even scorn, worthy of notice only as prime examples of pseudoscience in vivid contrast to true geological science. Some geologists seem to regard Theories of the Earth as a "wretched subject"—a verdict few geology-historians cared to appeal before the rise of recent perspectives of neocatastrophism and the success of the asteroid-impact hypothesis.[63]

For one so inclined (and Lyell was so inclined), Theories of the Earth are surprisingly easy to ridicule. The particular issues they often debated, the types of evidence they sometimes employed, and the nature of many of their conclusions often fall beyond the conventional boundaries of present-day natural science. Current standards might place them in the company of science fiction fantasy at best, or more likely, outright pseudoscience such as crop circles and UFO's. As with recent Hollywood extravaganzas such as *Deep Impact* and *Armageddon*, an unsympathetic modern reader might find it hard not to think of Chicken Little when reading William Whiston's *New Theory of the Earth* (1696), which prophesied an impending apocalyptic doom from a cometary conflagration of the world.[64] Whiston

[62] Mary Jo Nye, "New Views of Old Science," in *Encyclopedia Britannica Yearbook of Science and the Future: 1992* (Chicago: Encyclopedia Britannica, 1992), 225.

[63] Alleged cases of pseudoscience, fraud and fallacy are surveyed in Trevor J. Pinch and Harry M. Collins, "Private Science and Public Knowledge: The Committee for the Scientific Investitgation of the Claims of the Paranormal and its Use of the Literature," *Social Studies of Science* 14 (1984): 521–546; W. Hoyt, *Lowell and Mars* (Tucson: University of Arizona Press, 1976); on N-rays see Mary Jo Nye, *Science in the Provinces: Scientific Communities and Provincial Leadership in France, 1860-1930* (Berkeley: University of California Press, 1986); Felix Franks, *Polywater* (MIT Press, 1981); and Alexander Kohn, *False Prophets: Fraud and Error in Science and Medicine* (Cambridge, Mass.: Basil Blackwell, Inc., 1986). Otto Neugebauer defended giving historical attention to "wretched subjects" like astrology in Otto Neugebauer, "The Study of Wretched Subjects," *Isis* 42 (1951): 111. A representative work of recent neo-catastrophism is Derek Ager, *The New Catastrophism: The Rare Event in Geological History* (Cambridge: Cambridge University Press, 1993).

described how a comet could cause a deluge if it sideswiped the Earth while descending toward the Sun, but result in a conflagration if it encountered the Earth *after* its pass by the Sun:

> As we have given an Account of the Universal Deluge from the Approach of a Comet in its descent towards the Sun; so it will not be difficult to account for the General Conflagration from the like Approach of a Comet in its Ascent from the Sun. For 'tis evident from what has been already explain'd, that in case a Comet pass'd behind the Earth, tho' it were in its Descent, yet if it came near enough, and were it self big enough, it wou'd so much retard the Earth's annual Motion, and oblige it to revolve in an Ellipsis so near to the Sun in its Perihelion, that the Sun it self wou'd scorch and burn, dissolve and destroy it in the most prodigious degree; and this Combustion being renew'd every Revolution, wou'd render the Earth a perfect Chaos again, and change it from a Planet to a Comet for ever after.[65]

The comet would skew the Earth into a more elliptical orbit, according to Whiston, that would repeatedly bring it perilously near to the Sun. But even before the Sun would reduce the Earth to Chaos, its oceans and seas would have dried up and its atmosphere become inflamed due to the mere proximity to the comet:

> The vapours acquir'd from the Comet's Atmosphere, which at the Deluge were, by reason of their long absence from the Sun in the remote Regions beyond Saturn, pretty cool; at this time must be suppos'd, by reason of their so late and near approach to the Sun about the Perihelion, exceeding hot and burning; and that to so extraordinary a degree, that nothing but the Idea of the Mouth of a Volcano, just belching out immense quantities of liquid and burning Streams, or Torrents of fiery Matter, can in any measure be suitable to the Violence thereof. Imagine, therefore, the Earth to pass through the very middle of this Atmosphere, for 7000 or 8000 Miles together, and to bear off with it a Cylindrical Column thereof...[66]

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[64] Fears of cosmic collisions were revived in the last two decades of the twentieth century, bolstered by publicity surrounding the impact of Comet Shoemaker-Levy 9 with Jupiter. Observing programs were established to monitor Earth-orbit-crossing asteroids, justified by reference to the death of the dinosaurs. Regardless of the outcome of the asteroid-impact debates, it is to be hoped that the revival of neocatastrophic theories in planetary geology might facilitate a more sympathetic historical reassessment of Theories of the Earth.

[65] William Whiston, *A New Theory of the Earth, from its Original, to the Consummation of all Things. Wherein The Creation of the World in Six Days, The Universal Deluge, And the General Conflagration, As laid down in the Holy Scriptures, Are shewn to be perfectly agreeable to REASON and PHILOSOPHY. With a large Introductory Discourse concerning the Genuine Nature, Stile, and Extent of the Mosaick History of the CREATION* (London: Printed by R. Roberts, for Benj. Tooke, 1696), 368. Hereafter Whiston.

[66] Whiston, 370–371.

No popular preacher could have wished for better hellfire and brimstone sermon material.

In "A Voyage to Laputa," Whiston's contemporary Jonathan Swift remorselessly satirized the Theories of Whiston and others.[67] Pamela Gossin explains:

> Swift strongly objected to science replacing one set of superstitious fears with another. He uses this ironic result of science to great effect in the "Voyage to Laputa" in *Gulliver's Travels* where the Laputans have overcome superstitious associations with comets only to replace them with scientific predictions of a possible future collision. Although their theory predicts that such an event may occur far into the future, the Laputans are daily racked with fear and oddly obsessed with the pleasure of contemplating such 'scientifically' induced terror. Halley's own notions apparently had a similar effect on his own society, to such an extent that he felt the need to present public lectures in which he tried to assuage his audience's welling panic over upcoming celestial events by enlisting their assistance in collecting observations.[68]

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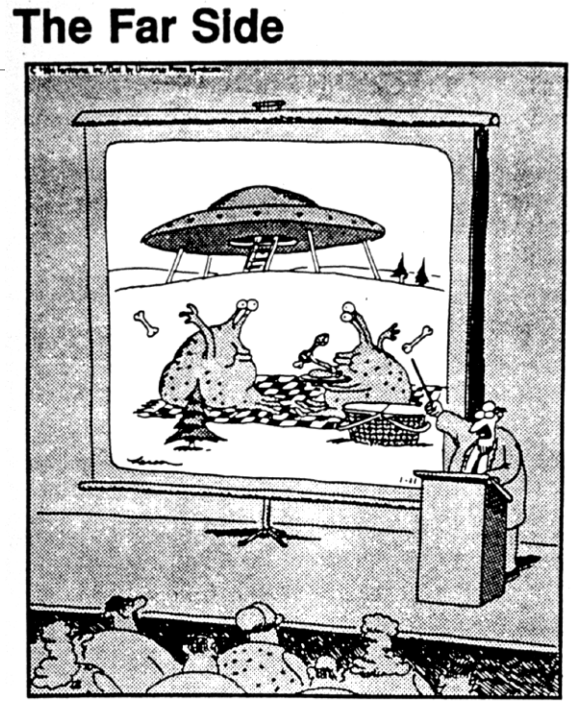
[67] Swift, *Gulliver's Travels*, III.II, 162–163: "These people are under continual disquietudes, never enjoying a minute's peace of mind; and their disturbances proceed from causes which very little affect the rest of mortals. Their apprehensions arise from several changes they dread in the celestial bodies. For instance, that the earth, by the continued approaches of the sun towards it, must in course of time be absorbed or swallowed up. That the face of the sun will by degrees be encrusted with its own effluvia, and give no more light to the world. That the earth very narrowly escaped a brush from the tail of the last comet, which would have infallibly reduced it to ashes; and that the next, which they have calculated for one and thirty years hence, will probably destroy us. For, if in its perihelion it should approach within a certain degree of the sun (as by their calculations they have reason to dread), it will conceive a degree of heat ten thousand times more intense than that of a red-hot glowing iron, and in its absence from the sun, carry a blazing tail ten hundred thousand and fourteen miles long; through which if the earth should pass at the distance of one hundred thousand miles from the nucleus or main body of the comet, it must in its passage be set on fire, and reduce to ashes. That the sun daily spending its rays without any nutriment to supply them, will at last be wholly consumed and annihilated; which must be attended with the destruction of this earth, and of all the planets that receive their light from it. They are so perpetually alarmed with the apprehensions of these and the like impending dangers, that they can neither sleep quietly in their beds, nor have any relish for the common pleasures or amusements of life. When they meet an acquaintance in the morning, the first question is about the sun's health, how he looked at his setting and rising, and what hopes they have to avoid the stroke of the approaching comet."

[68] Pamela Gossin, "Poetic Resolutions of Scientific Revolutions: Astronomy and the Literary Imaginations of Donne, Swift, and Hardy" (Ph.D. dissertation, University of Wisconsin-Madison, 1989), 317. Ernest Tuveson notes: "Whiston, indeed, was something of a Huxley to Newton and Halley; and his sensational explanations of the creation, deluge, and Millennium in terms of comets went a long way to popularize the new celestial mechanics. Thus, while comets lost the aura of mystery which had surrounded them when they had been considered as supernatural omens of dire events, they gained an awesome reputation as the preappointed instruments of eschatology." Ernest Tuveson, "Swift and the World-Makers," *Journal of the History of Ideas*, 1950, 11: 54–74, on p. 56. See also Marjorie Hope Nicolson, "The Scientific Background of Swift's 'Voyage to Laputa'," in *Science and Imagination*, 110–154 (Ithaca: Cornell University Press, 1956), Simon Schaffer, "Newton's Comets and the Transformation of Astrology," in *Astrology, Science and Society: Historical Essays*, ed. Patrick Curry (Wolfeboro, New Hampshire: Boydell Press, 1987), 219–243, and Sara Schechner Genuth, *Comets, Popular Culture, and the Birth of Modern Cosmology* (Princeton: Princeton University Press, 1997).



Professor Ferrington and his controversial theory that dinosaurs were actually the discarded "chicken" bones of giant, alien picnickers.

FIGURE 32. Gary Larson, *The Far Side*

Caption. "Professor Ferrington and his controversial theory that dinosaurs were actually the discarded 'chicken' bones of giant, alien picnickers."

The amusement provided by Theorists of the Earth extends to modern times, as revealed in the cartoon by Gary Larson (Figure 32) parodying Voltaire who, in the mid-eighteenth century, rejected claims that fossil fish on the heights of the Alps were originally deposited in a marine environment. Rather, he suggested, they might be the petrified remains of lunches discarded by pilgrims making their way back over the mountains from the Holy Land. However, the joke should not be at Voltaire's expense, for Voltaire himself was poking fun at a number of eighteenth-century Theories. After surveying six different recensions of Voltaire's pilgrim story, Marguerite Carozzi concludes that it "never was a serious proposition." Rather, Voltaire advocated a *freshwater* origin for the fossils now found on the tops of mountains: "It is quite evident that this funny story is concocted to amuse and to undermine the different systems on the presence of fossils in mountains. Thus, he would rather have pilgrims carry fossils than believe in the marine origin of some petrifactions found in mountains."[69] Lyell agreed that Voltaire was only "pretending" when recounting the pilgrim story, in order, as he thought, to undermine the diluvial views of the vulgar.[70]

[69] Marguerite Carozzi, "Voltaire's Attitude Toward Geology," *Archives des Sciences*, 1983, 36: 68–73.
[70] Lyell, *Principles*, 1: 66.

As Lyell noted, Theories of the Earth often were allied with diluvial views and to many historical actors and modern readers they are guilty by association. Despite contemporary refutation by Theorists such as Nicholas Hartsoeker, John Arbuthnot, and Thomas Robinson, and its inconsistency with findings reported in the widely-respected *Geographia Generalis* of Bernhard Varenius (1622-1650), Woodward's claim that the strata were sorted out in layers according to their specific gravities has been hailed in the twentieth century by the prominent young-Earth creationist Henry Morris as a still-valid principle that undermines modern ancient-Earth interpretations of the geological column.[71] Even before the outbreak of twentieth-century young-Earth creationism, Immanuel Velikovsky constructed a theory of the Earth that in its use of idiosyncratic methodologies and eccentric multidisciplinary scholarship may seem straight out of the Theories of the Earth tradition.[72] To their considerable annoyance, geologists experienced great difficulty in persuading the public of Velikovsky's errors which, with the surprising popular success of young-Earth creationism, understandably heightens their antagonism toward sweeping reconstructions of their discipline by outsiders past or present.[73]

Despite the sour taste of these present-day vestiges, for their own time Theories of the Earth cannot be dismissed as a pseudoscientific prelude to scientific geology. Though they

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71 Young-Earth creationism may be regarded as emerging in its widespread popular form with the publication of Henry Morris and John Whitcomb, *The Genesis Flood*, 1960. The standard survey of the origins of young-Earth creationism or "Flood Geology" is Ronald L. Numbers, *The Creationists: The Evolution of Scientific Creationism* (New York: Alfred A. Knopf, 1992). Woodward's Theory is discussed in "Mosaic Theories: Fossil Emplacement by Diluvial Dissolution," beginning on page 641.

72 Immanuel Velikovsky, *Worlds in Collision* (Garden City, NY: Doubleday and Company, 1950). Martin Gardner charges Velikovsky with over-reliance (often unattributed) upon the Theories of William Whiston and Ignatius Donnelly; cf. Martin Gardner, *Fads and Fallacies in the Name of Science,* 2d ed. (New York: Dover, 1957), 32–35. However, Secord suggests one difference between Velikovsky and Theories of the Earth: "Comparisons of Chambers with Immanuel Velikovsky, whose *Worlds in Collision* created a sensation in the 1950s, are entirely inappropriate, for the boundaries of expertise had become far sharper and Velikovsky's status as an outsider was relatively clear." James A. Secord, "Introduction," in Robert Chambers, *Vestiges of the Natural History of Creation and Other Evolutionary Writings*, ed. James A. Secord (Chicago: University of Chicago Press, 1994), xliv, note 75; hereafter Secord, "Introduction."

73 Henry H. Bauer, *Beyond Velikovsky: The History of a Public Controversy* (Urbana: University of Illinois Press, 1984). Bauer's analysis of the persistence of the Velikovsky controversy and the inability of expert scientists to establish closure in public debates seems more widely applicable to other folk-science controversies as well, including young-Earth creationism. Cf. comments on folk science above, in "Textual versus Technical Traditions," beginning on page 79.

seem vulgar and out-of-date to modern geologists, many were sophisticated, up-to-date syntheses of natural knowledge in their own day, as could be illustrated by considering any number of works from the founding texts of the tradition by René Descartes or Thomas Burnet to late works such as Cuvier's "Discours préliminaire" or the *Vestiges of the Natural History of Creation* by Robert Chambers (1844).

Cuvier is considered in the next section, but Chambers defended *Vestiges* as an "organic cosmogony" no more difficult to justify as a scientifically-legitimate discourse than works in "physical cosmogony."[74] *Vestiges* was the "carefully crafted product of a leading journalist and author"—while not the production of an insider possessing his own scientific expertise, it did attempt to incorporate specialist knowledge to support its broad vision of progressive development.[75] In an interesting example of the difference between writing in a technical field and writing in a textual tradition, Chambers decried the limited vision of specialists who produced their technical works without considering the broader relations of knowledge:

> ... nearly all the scientific men are opposed to the theory of the Vestiges.... It is no discredit to them, that they are, almost without exception, engaged, each in his own little department of science, and able to give little or no attention to other parts of that vast field. From year to year, and from age to age, we see them at work, adding no doubt much to the known, and advancing many important interests, but, at the same time, doing little for the establishment of comprehensive views of nature. Experiments in however narrow a walk, facts of whatever minuteness, make reputations in scientific societies; all beyond is regarded with suspicion and distrust.[76]

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[74] [Robert Chambers], *Explanations: A Sequel to "Vestiges of the Natural History of Creation." By the Author of that Work* (London: John Churchill, Princes Street, Soho, 1845); reprinted facsimile Robert Chambers, *Vestiges of the Natural History of Creation and Other Evolutionary Writings*, ed. James A. Secord (Chicago: University of Chicago Press, 1994), 170; hereafter Chambers, *Explanations*. The very description of *Vestiges* as a "natural history of creation" suggests its relationship with Theories of the Earth as a grand narrative of physical and organic development "from nebula to man." Similarly, an attempted refutation of *Vestiges* by Hugh Miller, *Footprints of the Creator* (1849), displays strong affinities with the public debates of the Theories of the Earth tradition.

[75] James A. Secord, "Behind the Veil: Robert Chambers and *Vestiges*," in *History, Humanity and Evolution: Essays for John C. Greene*, ed. James R. Moore (Cambridge: Cambridge University Press, 1989), 187.

[76] Chambers, *Explanations*, 175–176.

James Secord insists that "*Vestiges* was not a bungled attempt to produce 'professional' science, but a skilled intervention in some of the great public debates of the nineteenth century." Rather than a trickle-down popularization, Secord argues that in the *Vestiges* "Consequences that had been concealed by disciplinary boundaries are made explicit and inescapable."[77] Secord's introduction does much to restore an adequate appreciation of Chambers' competent grasp of contemporary natural knowledge. For example, in reporting Andrew Cosse's alleged creation of insects through electricity, Secord argues that "in fact *Vestiges* displays a knowledge of this controversy which is much more sophisticated than that of most modern commentators."[78] Similarly, Ogilvie charts how *Vestiges* was continually reworked to stay abreast of current discussions, such as Lord Rosse's telescopic observations which putatively challenged Laplace's nebular hypothesis.[79]

To return to our example, William Whiston's *New Theory of the Earth* incorporated not only Newton's celestial mechanics but also Halley's cometary theory, and helped to popularize both. A quick perusal of a table of contents for Whiston's work (not provided in the original text, but compiled in Table 38) reveals its putative geometrical form, with Postulates, Lemmata, Hypotheses, Phenomena, and Solutions imitating the *Mathematical Principles of Natural Philosophy* to whose author it was dedicated. The various headings illustrate the diversity of Whiston's synthesis as he drew upon established scholarship and contributed to serious contemporary discussions in such areas as biblical exegesis, classical geography, and the exact-

77 Secord, "Introduction," xliv and xiv. Secord explains (p. x) that the characterization of *Vestiges* as amateurish derives from "the received history of theories of species origins during the past two centuries.... The modern synthetic theory of evolution, in which natural selection plays a crucial role, is a twentieth-century creation. So too is the overwhelming centrality given to Darwin and the 'Darwinian Revolution' by biologists from Julian Huxley to Ernst Mayr. From this perspective, *Vestiges* is dismissed as an amateurish 'forerunner,' a curious episode on the road to the *Origin*." See the earlier discussion of popular and folk science in "Textual versus Technical Traditions," beginning on page 79.

78 Secord, "Introduction," xv. Cf. James A. Secord, "Extraordinary Experiment: Electricity and the Creation of Life in Victorian England," in *The Uses of Experiment: Studies in the Natural Sciences* (Cambridge: Cambridge University Press, 1989), 471–472.

79 Marilyn Bailey Ogilvie, "Robert Chambers and the Successive Revisions of the *Vestiges of the Natural History of Creation*" (Ph.D. dissertation, University of Oklahoma, 1973); and Marilyn Bailey Ogilvie, "Robert Chambers and the Nebular Hypothesis," *British Journal for the History of Science* 8 (1975): 214–232.

ing field of chronology.[80] This is not to argue that Theories of the Earth amounted to an incipient geology, nor to suggest that they achieved a consensus about the character of appropriate theorizing, but merely that as a textual tradition they were not necessarily and inherently pseudoscientific given the great heterogeneity of their topics and discursive contexts.[81]

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80 Whiston's Theory is explored at greater length below in "A Newtonian Cosmogony: Whiston's Hexameral Theory," beginning on page 584.

81 Here Butterfield's suggestion for how a historian may avoid Whiggism seems particularly apt: "Instead of being moved to indignation by something in the past which at first seems alien and perhaps even wicked to our own day, instead of leaving it in the outer darkness, he makes the effort to bring this thing into the context where it is natural, and he elucidates the matter by showing its relation to other things which we do understand." Butterfield, *Whig Interpretation of History*, 17.

TABLE 38. Outline of contents, Whiston's Theory of the Earth

Whiston, William. A New Theory of the Earth, from its Original, to the Consummation of all Things. Wherein The Creation of the World in Six Days, The Universal Deluge, And the General Conflagration, As laid down in the Holy Scriptures, Are shewn to be perfectly agreeable to REASON and PHILOSOPHY. With a large Introductory Discourse concerning the Genuine Nature, Stile, and Extent of the Mosaick History of the CREATION. London: Printed by R. Roberts, for Benj. Tooke, 1696		
Frontispiece (Solar System)		
Latin dedication to Isaac Newton		
A Discourse Concerning the Nature, Stile, and Extent of the Mosaick History of the Creation		1–94
Postulata		95
I	The Obvious or Literal Sense of Scripture is the True and Real one, where no evident Reason can be given to the contrary	
II	That which is clearly accountable in a natural way, is not without reason to be ascrib'd to a Miraculous Power	
III	What Ancient Tradition asserts of the constitution of Nature, or of the Origin and Primitive States of the World, is to be allow'd for True, where 'tis fully agreeable to Scripture, Reason, and Philosophy	
7 pages of diagrams illustrating cometary mechanics		
A New Theory of the Earth		1–388
Book I. Lemmata		1–67
83 Lemmata often elaborated by corollaries, or followed by scholia		
7 Scholia: after Lemmata III, XIII, XV, XXX, XXXII, XXXIII, XLVII		
Book II. Hypotheses		69–156
I	The Ancient Chaos, the Origin of our Earth, was the Atmosphere of a Comet (9 supporting arguments)	69–76
II	The Mountainous Columns of the Earth are not so dense or heavy as the other Columns (5 supporting arguments)	76–79
III	Tho' the Annual Motion of the Earth commenc'd at the beginning of the Mosaick Creation; yet its Diurnal Rotation did not till after the Fall of Man (5 related arguments)	79–104
IV	The ancient Paradise or Garden of Eden, the Seat of our first Parents in the State of Innocence, was at the joynt Course of the Rivers Tigris and Euphrates; either before they fall into the Persian Gulf, where they now unite together, and separate again; or rather where they anciently divided themselves below the Island Ormus, where the Persian Gulf, under the Tropick of Cancer, falls into the Persian-Sea (4 supporting arguments)	104–106
V	The Primitive Ecliptick, or its correspondent Circle on the Earth, intersected the Present Tropick of Cancer at Paradise; or at least at its Meridian (3 supporting arguments)	106–108
VI	The Patriarchal, or most ancient Year mention'd in the Scripture, began at the Autumnal Equinox (7 supporting arguments)	108–110

TABLE 38. **Outline of contents, Whiston's Theory of the Earth**

VII	The Original Orbits of the Planets, and particularly of the Earth, before the Deluge, were perfect Circles (7 supporting arguments)	110–118
VIII	The Ark did not rest, as is commonly suppos'd, in Armenia; but on the Mountain Caucasus, or Paropamisus, on the Confines of Tartary, Persia, and India (5 supporting arguments)	119–123
IX	The Deluge began on the 17th Day of the second Month from the Autumnal Equinox, (or on the 27th Day of November in the Julian Stile extended backward) in the 2365th year of the Julian Period, and in the 2349th year before the Christian Æra	123–126
X	A Comet, descending, in the Plain of the Ecliptick, towards its Perihelion; on the first Day of the Deluge past just before the Body of our Earth (Essay followed by 5 supporting arguments plus a scholium)	126–156
Book III. Phænomena		157–215
I	Phænomena relating to the Mosaick Creation, and the Original Constitution of the Earth (Phen. 1–22)	157–168
II	Phænomena relating to the Primitive State of the Earth (Phen. 23–32)	168–174
III	Phænomena relating to the Antediluvian State of the Earth (Phen. 33–43)	174–187
IV	Phænomena relating to the Universal Deluge, and its Effects upon the Earth (Phen. 44–89)	187–208
V	Phænomena relating to the General Conflagration. With Conjectures pertaining to the same, and to the succeeding period till the Consummation of all things (Phen. 90–100. Scholium after phen. 90)	209–215
Book IV. Solutions: Or, An Account of the foregoing Phænomena from the Principles of Philosophy already laid down		217–378
I	A Solution of the Phænomena relating to the Mosaick Creation, and the original Constitution of the Earth (Sols. 1-22. Reprints 5 of Burnet's illustrations)	217–264
II	A Solution of the Phænomena relating to the Primitive State of the Earth (Sols. 23–32. Scholium after solution 28 on the Fall)	265–282
III	A Solution of the Phænomena relating to the Antediluvian State of the Earth (Sols. 33–43)	282–300
IV	A Solution of the Phænomena relating to the Universal Deluge, and its Effects upon the Earth (Sols. 44–89)	300–367
V	Phænomena relating to the General Conflagration: with Conjectures pertaining to the same; and to the succeeding Period, till the Consummation of all things (Sols. 90–100)	368–378
Corollaries from the Whole (Final section of 7 corollaries)		378–382
A Postscript		
A chronological addendum		

§ 5. Controversy and the Rhetoric of Demarcation

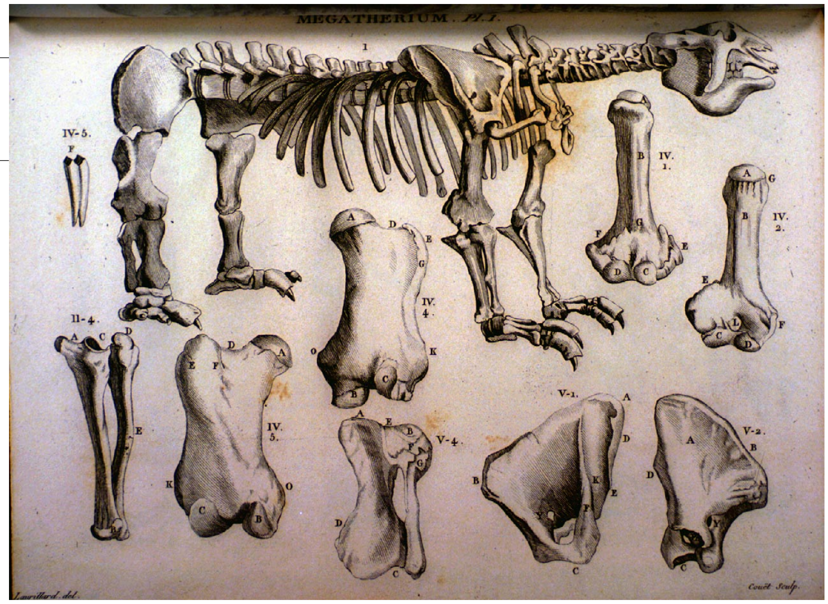

FIGURE 33. Cuvier's *Megatherium* (1812). HSCI.

Explanation. After its discovery in the New World and reconstruction at the Royal Museum in Madrid by Juan-Bautista Bru (1740–1799), in 1796 Cuvier classified the elephant-sized animal as a slothlike edentate and argued that it must be extinct.[82]

The Theory of the Earth of Georges Cuvier (1769–1832) was based upon the celebrated techniques he developed in comparative anatomy by which he reconstructed extinct quadrupeds from fragments of their fossilized bones.[83] His expertise in quadrupeds such as living and fossil elephants directed his attention to the

[82] Figure 33 is from *Recherches sur les Ossemens Fossiles de quadrupedes où l'on établit les caractères de plusieurs espèces d'animaux que les révolutions de globe paroissent avoir détruites*, 5 vols. (Paris: Chez Deterville, 1812), vol. 4. For a discussion and translation of Cuvier's original paper, "Squelette trouvé au Paraguay" (1796), see Martin J. S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), chapter 3; hereafter Rudwick, *Georges Cuvier.*

[83] Cuvier's Theory of the Earth comprised the opening essay of his major study of fossil quadruped bones; Georges Cuvier, "Discours préliminaire," in *Recherches sur les Ossemens Fossiles de quadrupedes où l'on établit les caractères de plusieurs espèces d'animaux que les révolutions de globe paroissent avoir détruites*, vol. 1, 5 vols. (Paris: Chez Deterville, 1812), 1–116; hereafter Cuvier, "Discours préliminaire." It was frequently reprinted with significant revisions by Cuvier; e.g, Georges Cuvier, *Discours sur Les Révolutions de la surface du globe, et sur les changemens qu'elles ont produits dans le règne animal*, 3d ed. (Paris, et à Amsterdam: chez G. Dufour et Ed. d'Ocagne, 1825). One year after the first edition an English translation by Robert Kerr was published with extensive annotations by Robert Jameson, Georges Cuvier, *Essay on the Theory of the Earth. Translated from the French of M. Cuvier... by Robert Kerr. With Mineralogical Notes, and an Account of Cuvier's Geological Discoveries, by Professor Jameson* (Edinburgh: Printed for William Blackwood; and John Murray, and Robert Baldwin, 1813); this was reprinted with substantial revisions to the annotations by Robert Jameson in 1815, 1817, 1818, 1822 and 1827; hereafter Cuvier, *Theory of the Earth* (year of publication). Other editions are noted in footnote 11 on page 268. Jameson's editions are cited here because they were the chief source for British and American contemporaries; any non-trivial divergences in Kerr's translation from Cuvier's text are noted. Several texts displaying the techniques of Cuvier's earlier comparative anatomy at work are translated with commentary in Rudwick, *Georges Cuvier.* This work also includes Rudwick's translation of the "Discours préliminaire." Important general sources for Cuvier include Dorinda Outram, *Georges Cuvier: Vocation, Science, and Authority in Post-Revolutionary France* (Manchester: Manchester University press, 1984) and Jean Chandler Smith, *Georges Cuvier: An Annotated Bibliography of his Published Works* (Washington: Smithsonian Institution Press, 1993).

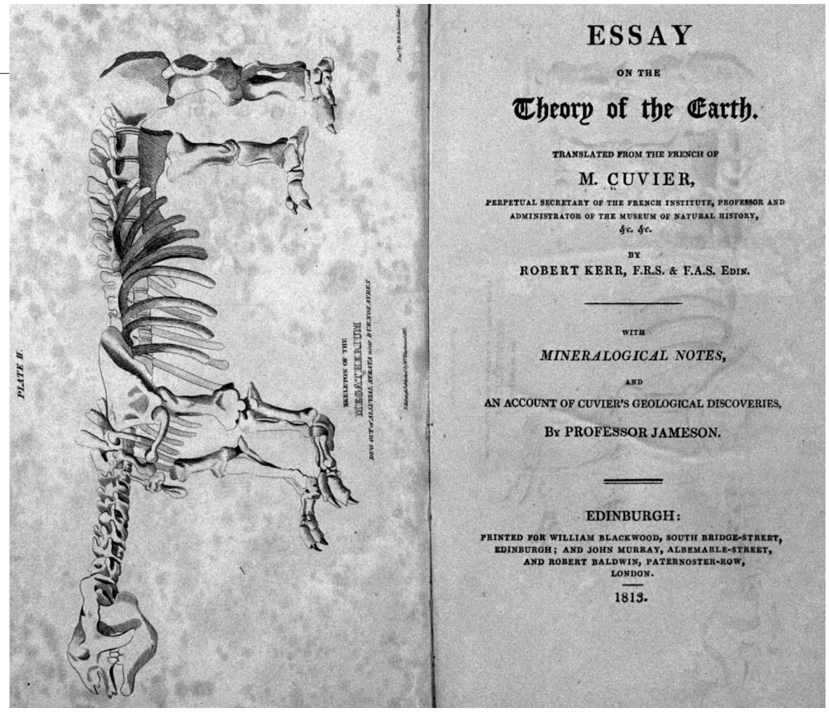

FIGURE 34. Megatherium skeleton, reproduced in Jameson's 1813 edition of Cuvier's *Theory of the Earth*. HSCI.

more recent Secondary formations in which they occurred, rather than the mineral-rich Primary formations.[84] Thus Cuvier accompanied Alexandre Brongniart (1770–1847) in a geognostical study of the recent Secondary formations resting above the Chalk in the Paris basin. In this fieldwork Brongniart and Cuvier decided that the formations were characterized by the invertebrate and other fossils they contained, whether marine, freshwater, or

[84] In an 1807 review of a contemporary Theory of the Earth, Cuvier explained: "We forget indeed that we are talking not only of the nature and arrangement of the interior of the globe, but (also) of that of its outermost skin. The research of miners, of Pallas, Saussure, Deluc, and Dolomieu, and of the Werner school, have given us valuable generalizations—although not yet beyond challenge—on the Primary rock-masses (*montagnes*). But the Secondary formations (*terrains*), which are the most awkward part of the problem, have scarcely been touched upon; the most crucial points, on which necessarily depend the side that one takes in relation to causes, are still in question." Georges Cuvier, "Rapport sur l'ouvrage de M. André," trans. Martin J. S. Rudwick in *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (Chicago: University of Chicago Press, 1997), 105; hereafter Cuvier, Report on André. This brief report contains the major themes of Cuvier's criticisms of Theories of the Earth in the "Discours préliminaire."

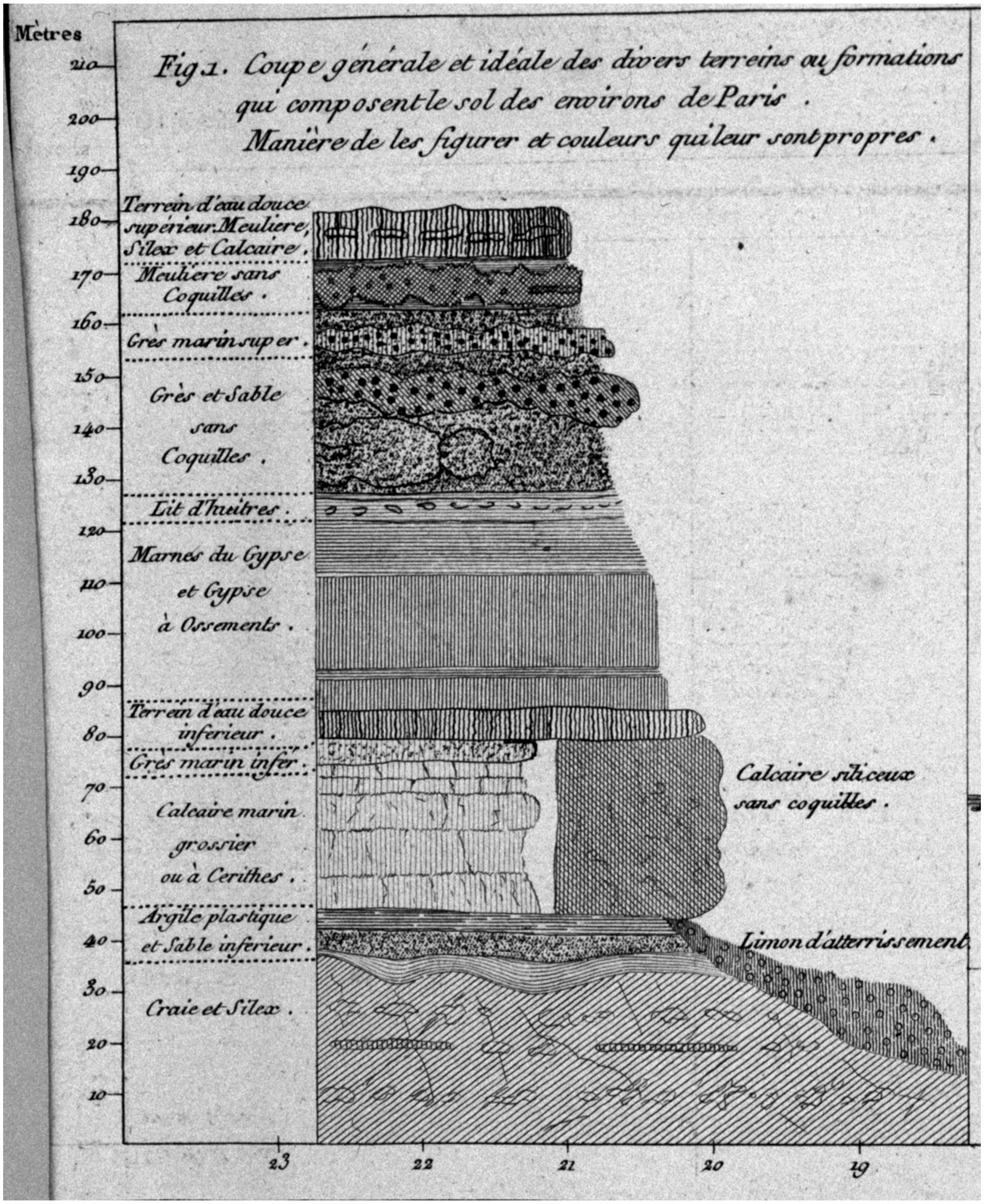

FIGURE 35. Cuvier and Brongniart, 1811; Paris basin, *Plate I, Figure 1*. HSCI.

Explanation. In the Paris basin Brongniart and Cuvier described a succession of distinct marine, freshwater, and terrestrial formations above the flint-bearing Chalk (*Craie et Silex*), although the Chalk hitherto had been regarded by geognosts as one of the most recent formations.

terrestrial (Figure 35).[85] By the alternation of formations so described they determined that at least one incursion of the sea had intervened since land mammals lived in that location during a previous age. Backed by his anatomical reconstructions, Cuvier argued for the extinction of earlier land mammals—such as Jefferson's *Megalonix*, the *Megatherium* from modern Argentina (Figure 33 and Figure 34), and the *Palaeotherium* and *Anoplotherium* which Cuvier discovered in the Gypsum formation—probably as a result of the incursion of the sea.[86] A hitherto unsuspected ancient world once flourished in France, then vanished in one of the last revolutions of the globe.

Cuvier's assertion that many kinds of animals were extinct contradicted the transformist views of his colleagues Jean Baptiste Pierre Antoine de Monet de Lamarck (1744–1829) and Jean Claude de Lamétherie (1743–1817), both of whom had supported their views in Theories of the Earth.[87] If his scope did not quite reach "from nebula to Napoleon," nevertheless by connecting in one continuous series "from granite to gravel" the familiar Primary formations beneath the Chalk with the recent formations lying above it, Cuvier's Theory of the Earth forged a powerful "directionalist synthesis" upon a Wernerian foundation.[88] At the

85 Cf. Georges Cuvier and Alexandre Brongniart, "Essai sur la Géographie Minéralogique des Environs de Paris," *Annales du Muséum d'Histoire Naturelle* 11 (1808): 293–326; an expanded version, including a color map, was published three years later as Georges Cuvier and Alexandre Brongniart, "Essai sur la Géographie Minéralogique des Environs de Paris (lu 11 avril 1808)," *Mémoires de la Classe des Sciences Mathématiques et Physiques de l'Institut Impérial de France* 1811: 1–278. The 1811 version includes Figure 35, which was reprinted in the first volume of *Recherches sur les Ossemens Fossiles de quadrupedes* (1812). For an English translation of the 1808 version see Rudwick, *Georges Cuvier*, chapter 12. Rudwick notes that this collaboration "was the only substantial piece of geological fieldwork he [Cuvier] ever did. However, the field research was mainly due to Brongniart, as Cuvier in fact later acknowledged, with uncharacteristic generosity." Rudwick, *Georges Cuvier*, 128. On early investigations in the Paris basin see Jean Gaudant, "L'exploration géologique du Bassin Parisien: Quelques pionniers, le plus souvent méconnus," *Histoire et Nature* 30 (1993): 17–40.

86 Some of Cuvier's unpublished illustrations of reconstructed animals are reprinted in Rudwick, *Georges Cuvier*.

87 Jean Baptiste Pierre Antoine de Monet de Lamarck, *Hydrogéologie ou Recherches sur l'influence qu'ont les eaux sur la surface du globe terrestre; sur les causes de l'existence du basin des mers, de son déplacement et de son transport successif sur les différens points de la surface de ce globe; enfin sur les changemens que les corps vivans exercent sur la nature et l'état de cette surface* (Paris: Chez l'Auteur; Agasse; Maillard, An 10, 1802), available in translation as Lamarck, *Hydrogeology*, trans. Albert V. Carozzi (Urbana: University of Illinois Press, 1964). Jean Claude De La Métherie, *Theorie de la terre*, 3 vols. (Paris: Chez Maradan, An III, 1795); this vast survey of systems of geology was reprinted in 5 vols. in 1797. On Lamétherie see Carleton E. Perrin, "The Triumph of the Antiphlogistians," in *The Analytic Spirit: Essays in the History of Science in Honor of Henry Guerlac*, ed. Harry Woolf (Ithaca: Cornell University Press, 1981), 40–63; and the article by Kenneth L. Taylor in the *Dictionary of Scientific Biography.*

same time, Cuvier and Brongniart introduced new techniques and evidential criteria contrary to Wernerian geognosy for correlating the recent formations by means of fossil evidence (to which they subordinated geognostical structural relations). Because these techniques of correlation demonstrated a succession of ancient worlds, each with its own flora and fauna now extinct, Cuvier's Theory of the Earth provided an alternative, he believed, to visions of biological transformism whether nondirectionalist (Lamarck's) or directionalist (St. Hilaire's). It is no surprise that Cuvier dismissed the Theory of Lamarck with severe rhetoric in a Theory of the Earth which established a foundation for his lifelong anatomical research program.[89]

[88] The phrase "from granite to gravel" is Robert Jameson's: "The discoveries of Cuvier, Brongniart, and Webster... have added a most interesting and curious set of rocks to the geognostic system. They have connected, more nearly than heretofore, the alluvial with the floetz formations, and have thus rendered more complete the series of rocks which extends from granite to gravel." Cuvier, *Theory of the Earth* (1817), 344–345. Nor was Jameson atypical in this assessment; contemporary geognosts universally regarded Cuvier and Brongniart's work as extending the geognostic research program (see below). For the meaning of "directionalist synthesis" see Martin J. S. Rudwick, "Uniformity and Progression: Reflections on the Structure of Geological Theory in the Age of Lyell," in *Perspectives in the History of Science and Technology*, ed. Duane H. D Roller (Norman: University of Oklahoma Press, 1971), 209–227. From "nebula to Napoleon" is not as far-fetched as it may sound since Cuvier dedicated his *Recherches sur les Ossemens Fossiles de quadrupedes* to Pierre Simon, marquis de LaPlace (1749–1827), and referred to Laplace in glowing terms in the "Discours préliminaire"; cf. Cuvier, *Theory of the Earth* (1817), 169 (however, Cuvier's references to Laplace reflect his admiration for the certainty of geometrical demonstration and positive science in contrast to speculative systems, and I have not found a reference by Cuvier to Laplace's nebular hypothesis). Although Cuvier discovered long pre-human epochs in the history of the Earth, to Cuvier his Theory "connects natural and civil history together in one uninterrupted series" and properly connects "the series, on the one hand, with the most solid and ancient formations, and on the other, with the recent alluvial depositions made by the Po, the Arno, and their tributary streams"; Cuvier, *Theory of the Earth* (1817), 133, 178. Cuvier preferred to emphasize the continuity of pre-human time with human history and employed antiquarian metaphors to describe his own accomplishments (as in the masterful opening paragraphs of the "Discours préliminaire"). In geological lectures delivered during a visit of the pope to Paris in 1805, Cuvier was reported to have opposed transformist views in favor of a Mosaic account of the origin of the globe in a sequence of six epochs; cf. Rudwick, *Georges Cuvier*, 87, 76–77.

[89] Cuvier began his criticism of two recent systems of geology—Lamarck's, which he treated as an extension of Maillet; and Patrin's, regarded as fashioned after Kepler—with these derogatory words: "In the present day, men of bolder imagination than ever, have employed themselves on this great subject...." Cuvier concluded by noting "these are what may be termed extreme examples,... all geologists have not permitted themselves to be carried away by such bold or extravagant conceptions as those we have just cited." Cuvier, *Theory of the Earth* (1817), 43, 45. On Cuvier and Lamarck see Goulven Laurent, "L'Histoire de la Terre et de la Vie en France au Temps de la Révolution: Cuvier et Lamarck," *Sciences et Techniques en Perspective* 10 (1985): 108–128; Goulven Laurent, "Cuvier et Lamarck: La querelle du catastrophisme," *La Recherche* 17 (1986): 1510–1518; Goulven Laurent, *Paléontologie et évolution en France de 1800 à 1860: une histoire des idées de Cuvier et Lamarck à Darwin* (Paris: Editions du Comité des Travaux Historiques et Scientifiques, C.N.R.S., 1987); and Claudine Cohen, "Lamarck et Benoît de Maillet (1656–1738)," in *Jean-Baptiste Lamarck, 1744-1829*, ed. Goulven Laurent, 483–496 (Paris: Editions CTHS, 1997). Transformism constituted a continual challenge to Cuvier's work, later represented by his colleague Geoffrey St. Hilaire. See also Toby A. Appel, *The Cuvier-Geoffroy Debate: French Biology in the Decades Before Darwin* (Oxford: Oxford University Press, 1987).

After the publication of William Buckland's *Reliquiae Diluvianae* (1823), perhaps the most significant of many works which appropriated Cuvier's Theory with its repeated incursions of the sea in the context of biblical diluvialism,[90] and Lyell's *Principles of Geology* (1830-1833), which was to become the chief rival to Cuvier's directionalist synthesis, Cuvier became regarded, particularly in England, as the advocate of an untenable and regressive catastrophism. Consistent with a career long characterized by the careful correction of Whiggish perspectives in the historiography of geology, Martin Rudwick has attempted to rescue Cuvier from such ill-deserved opprobrium. Earlier, Rudwick refuted widespread caricatures of Cuvier's catastrophism.[91] More recently, Rudwick has shown how Cuvier's catastrophism did not preclude his discovery and demonstration of the existence of vast prehuman ages of the Earth.[92]

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[90] William Buckland, *Reliquiae Diluvianae; or, Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on Other Geological Phenomena, Attesting the Action of an Universal Deluge* (London: John Murray, Albemarle-Street, 1823). Amos Eaton, an American admirer of Werner, Cuvier and Buckland, exemplifies this new diluvial synthesis: "The deluge no longer rests on the authority of written evidence. He [Buckland] points to records as durable as the earth, and far less changeable. The study of organized beings has become the most essential qualification for the study of geology; for their relics are the more sure guides to truth." Amos Eaton, *Geological Textbook, prepared for popular lectures on North American geology; with applications to agriculture and the arts* (Albany: Printed by Websters & Skinners, 1830), 14. Eaton is discussed further in "Amos Eaton, Fieldwork, and Wernerian Geognosy," beginning on page 695.

[91] "Cuvier's geological theory, which many years later was given the misleading name of 'catastrophism,' became widely known and influential among the general reading public as well as among men of science. Cuvier himself rarely used the word 'catastrophes,' for its overtones of disaster were largely extraneous to his conception of these regular and natural events; he preferred the term 'revolutions,' with its more Newtonian flavour." Martin J. S. Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology*, 2d ed. (London: Macdonald, and New York: American Elsevier, 1972; Chicago: University of Chicago Press, 1976), 132. A similar point is made below with respect to the cosmic catastrophism of Buffon, whose views were distorted in a manner similar to Lyell's caricatures of Cuvier; see "Ornamental Global Views in Buffon's Histoire naturelle," especially page 382; and note the discussion of "revolution" in "Revolutions of the Globe," beginning on page 114. Cf. Albert V. Carozzi, "Une Nouvelle Interprétation du Soi-disant Catastrophisme de Cuvier," *Archives des Sciences* 24 (1971): 367–377. The gross exaggerations of Cuvier's catastrophism which arose in subsequent polemics persist in historiography as recently as William F. Bynum, E. J. Browne and Roy Porter, eds., *Dictionary of the History of Science* (Princeton: Princeton University Press, 1981), s.v. "catastrophism" (p. 53; I thank Rhoda Rappaport for calling this example to my attention). Rudwick's laudable rehabilitation of Cuvier against such caricatures is not diminished merely by conceding that Cuvier's views of regional changes in the history of the Earth were not gradualistic: "These repeated irruptions and retreats of the sea have neither been slow nor gradual; most of the catastrophes which have occasioned them have been sudden; and this is easily proved, especially with regard to the last of them, the traces of which are most conspicuous"; "Every part of the globe bears the impress of these great and terrible events so distinctly...." Cuvier described these catastrophes as convulsions or successive revolutions comparable with the ravages of war; cf. Cuvier, *Essay on the Theory of the Earth* (1817), 15-16, 7. (Kerr's translation is accurate and does not distort Cuvier's metaphors or exaggerate his text in these quotations.)

Although brilliant and successful in its overall thrust, in one respect Rudwick's strategy unfortunately replays the demarcation rhetoric encountered above by geologist-historians of Hutton, just as Cuvier himself replayed D'Alembert's rhetorical tropes against Buffon and *l'esprit des systêmes*. That is, in order to emphasize the significance of Cuvier's Theory of the Earth for nineteenth-century geology (specifically, for the development of a sense of prehuman geohistory), Rudwick goes out of his way to detach Cuvier from the Theory of the Earth tradition.[93] Distinguishing his views from previous systems of geology, Cuvier wrote that none had sufficiently taken into account the relations of the extraneous fossils with the strata and formations containing them:

> All geologists hitherto have either been mere *cabinet naturalists*, who had themselves hardly paid any attention to the structure of mountains, or *mere mineralogists*, who had not studied in sufficient detail the innumerable diversity of animals, and the almost infinite complication of their various parts and organs. The former of these have only constructed systems; while the latter have made excellent collections of observations, and have laid the foundations of true geological science, but have been unable to raise and complete the edifice.[94]

The simplistic character of Cuvier's two categories is less important here than to observe that Cuvier was engaged in the rhetoric of boundary work, pressing the case that his techniques would bring unprecedented success where others merely groped in the dark.[95] Cuvier

[92] "Historical understanding and appreciation of Cuvier's work was until recently stultified by the perception that he had been doubly on the wrong side: wrong in his opposition to organic evolution and wrong in his claims for the reality of catastrophes. But modern approaches to the history of science, reinforced by the renewed acceptability of catastrophism among modern scientists, have now begun to restore Cuvier to his proper and prominent place in the history of science." Rudwick, *Georges Cuvier*, x.

[93] This strategy is especially clear in an article where Rudwick distills the argument of the book by distinguishing between four separate scientific practices around 1800: first, the study of fossils and minerals as cabinet specimens, a branch of natural history; second, the techniques of geognosy for identifying the structural relations of formations through fieldwork; third, theories of the Earth; and fourth, the synthesis of Cuvier himself. As shown below, the first two practices correspond to Cuvier's own historiography. Theories of the Earth—characterized as a distinct discipline and speculative genre unrelated to the other three practices—are simply dismissed as irrelevant. Of course, only the fourth, the work of Cuvier himself, was truly geohistorical in Rudwick's argument. Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 25–36.

[94] Cuvier, *Theory of the Earth* (1817), 51–52, italics added; this passage occurs within an especially revealing discussion where Cuvier offers his explanation for the errors of previous Theorists.

[95] A sustained examination of the role of boundary-work for defending claims of credibility in modern science is Thomas F. Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999).

counted more than eighty geological systems in his day, which he characterized as "based only on a very small number of partial [i.e., local] observations," or devised on the basis of "some principle, found in advance *a priori*." Echoing D'Alembert's distinction between a speculative spirit of system and a factual systematic spirit, Cuvier repudiated these premature attempts and counselled a nine-point agenda (prominently including further study of fossils) to "make geology a science of facts." Ironically, as was often the case, a Theorist's demarcation rhetoric proved to be double-edged: Cuvier critiqued other Theories of the Earth as controversial and fruitless only to be similarly critiqued himself.[96] As Rudwick laments, Cuvier's "later reputation was as a highly speculative 'theorist of the earth,' yet in his writing he repeatedly criticized that whole genre as a morass of ill-founded conjectures...." By thus lumping Theories of the Earth together into a monolithic "whole genre" distinct from Cuvier's work, Rudwick's disjunctive rhetorical maneuver merely endorses and repeats the rhetoric by which Cuvier sought, through denunciation of his predecessors, to establish the significance of his own techniques of comparative anatomy as a privileged source of evidence for knowledge of the Earth's past.[97]

Rudwick's strategy for rehabilitating Cuvier thus forcefully raises the question whether and in what sense Cuvier was a Theorist of the Earth, and we are compelled to return to the problem of demarcation and to enter a debate already conducted by the historical actors, a contest we have attempted to transcend.[98] By the textual criteria of self-attribution and participation, Cuvier saw himself as contributing to "the Theory of the Earth." Cuvier deployed his comparative anatomy from early in his career as an instrument for constructing a better Theory of the Earth (Table 39).[99] In 1796 he drew attention to the need for Theories of the

[96] Cuvier, Report on André, 104–105. This irony illustrates the caveats—particularly the fourth—proposed in the discussion of D'Alembert's similar rhetoric; cf. "System of the Earth," beginning on page 106.

[97] Rudwick, *Georges Cuvier*, 258. Cf. page 51 on disjunctive rhetorical maneuvers.

[98] See Chapter 1; the textual criteria are summarized in Table 10 on page 106.

[99] In the various quotations of Cuvier it is important to remember that "geology" and "system of geology" were sometimes used synonymously with "Theory of the Earth"; cf. the definition of Deluc, page 126.

Earth to draw upon anatomical evidence, but he did not yet dare to follow up in print on his questions. With further research and enhanced credibility, by 1804 he became more outspoken in declaring his right as a comparative anatomist to adjudicate Theories. The major recurring theme in this early work is the futility of Theories which failed to take account of anatomical fossil evidence. Although Cuvier's criticisms have much in common with the fact vs. theory rhetoric so effectively wielded by the English geologists,[100] Cuvier's repeated strictures against such Theories may reflect an ongoing transformation of the tradition into more technical disciplines such as paleontology, just as earlier demarcation rhetoric of Jameson and others evidenced the emergence of the technical tradition of geognosy. However, the same kind of rhetoric long had been employed in defense of every technical tradition whose practitioners participated in Theories of the Earth, whether on behalf of Steno's anatomy, Whiston's Newtonian cosmology, Woodward's natural history, or countless others. Because Theories of the Earth grade into technical traditions, it would be a mistake to take Cuvier's boundary work as proof that he single-handedly accomplished a final transformation of disciplines and made a complete break with the textual tradition. Not only did Cuvier critically rely upon previous Theorists such as Deluc, Pallas, Saussure, Werner, and others, but Cuvier introduced his "Discours préliminaire" as an "essay on a small part of the theory of the earth," aimed in part to "describe the whole of the results at which the theory of the earth seems to me to have arrived."[101] For Cuvier much disproof and reconstruction was required, but the single most important point is that the dialogue was *publicly* engaged—and sustained by revised and reprinted texts for nearly two decades.[102] For this reason it is not surprising that by the tex-

[100]Indeed, they may have learned it in part from Cuvier himself, since they also appropriated his historical characterizations of Theories of the Earth. See "System of the Earth," beginning on page 106.

[101]Cuvier, *Theory of the Earth* (1817), 2, 5; Rudwick, *Georges Cuvier*, 184, 186. Cuvier, "Discours préliminaire," 3-4: "Je retracerai dans ce Discours préliminaire l'ensemble des résultats auxquels il me paroît que la théorie de la terre est arrivée jusqu'à présent." Cf. François Ellenberger and Gabriel Gohau, "A l'Aurore de la Stratigraphie Paléontologique: Jean-André De Luc, Son Influence sur Cuvier," *Revue d'Histoire des Sciences* 34 (1981): 217–257.

[102]For editions, see footnote 83 on page 307 and footnote 11 on page 268.

tual criterion of external attribution Cuvier was definitely a Theorist, as Rudwick concedes, although Cuvier lived near the end of the textual tradition and helped to bring about its technical transformations. But it was not just later readers who interpreted Cuvier as a Theorist in retrospect, after the tradition had been displaced; his immediate contemporaries regarded Cuvier as a Theorist of the Earth. Acknowledged Theorists such as Robert Jameson welcomed Cuvier's views as a contribution to the Theory of the Earth, providing extensive mineralogical annotations to repeated editions in which he praised Cuvier, as noted above, for completing the Wernerian Theory "from granite to gravel."

TABLE 39. Cuvier's Anatomical Research relevant to Theories of the Earth

Work, year, page[a]	Quotation
Espèces des éléphans, 1796, 21, 24	There is "a science that does not appear at first sight to have such close affinities with anatomy; one that is concerned with the structure of the earth, that collects the monuments of the physical history of the globe, and tries with a bold hand to sketch a picture of the revolutions it has undergone: in a word, it is only with the help of anatomy that geology can establish in a sure manner several of the facts that serve as its foundations." "All these facts, consistent among themselves, and not opposed by any report, seem to me to prove the existence of a world previous to ours, destroyed by some kind of catastrophe. But what was this primitive earth? What was this nature that was not subject to man's dominion? And what revolution was able to wipe it out, to the point of leaving no trace of it except some half-decomposed bones? It is not for us to involve ourselves in the vast field of conjectures that these questions open up. Only more daring philosophers undertake that. Modern anatomy, restricted to detailed study and to the scrupulous comparison with other objects presented to its eyes and scalpel, will be content with the honor of having opened up this new highway to the genius who will dare to follow it."
Espèces de quadrupèdes, 1801, 47, 48, 57	"The theory of the earth has thus taken a new direction in the past twenty years. The Saussures, Pallases, and Dolomieus were less eager to attract the admiration of their contemporaries by brilliant but fragile edifices, than to set in place some solid foundations on which posterity could one day construct a lasting monument. They rejected all 'system'; they recognized that the first step to make in divining the past was to establish the present firmly. Since then, instead of imagining causes, one has collected facts." "However, this kind of fossil has no less interest than others for the theory of the earth...." "How much will the ideas we already had about the revolutions of the globe be enlarged by these circumstances that were hitherto unknown: animals that formerly lived on the earth's surface, buried under entire mountains; between them and the present surface, traces of the successive passages of seas; an earth, a primitive nature, which was not at all submissive to the empire of mankind, and of which only some half-decomposed bones remain to us! How were these antique organisms destroyed?"
Petit quadrupède du genre de sarigues, 1804, 71, 72	"But the object of my research is to procure light, not embarrassment, for geology.... Persuaded as I am of the futility of all these systems, I find myself pleased each time a well-established fact comes and destroys one of them."

a. Page references are to the translations in Martin J. S. Rudwick, Georges Cuvier, Fossil Bones, and Geological Catastrophes (Chicago: University of Chicago Press, 1997).

We have seen that Cuvier pigeon-holed previous Theorists into the two categories of "cabinet naturalists" and "mere mineralogists," where the latter refers to geognosts who gave what he regarded as insufficient attention to fossil evidence and comparative anatomy. That such rhetoric makes poor historiography is evident from the fact that contemporary geognosts, *i.e.*, "mere mineralogists," universally regarded Cuvier and Brongniart's work as extending the geognostic research program despite their occasional quarrels about whether to privilege inferences of geognostic structural relations or fossil evidence when interpreting recent formations. Consider the example of Alexander von Humboldt, who characterized Cuvier's use of fossils as a component rather than a contradiction of the methods of geognosy: "the profound study of fossil bodies comprehends but a small part of geognosy, but a part which is highly deserving of the attention of the philosopher." Humboldt repeatedly emphasized that Cuvier's use of fossil evidence complemented rather than displaced Wernerian geognosy:

> I believe, that the study of fossil organic bodies, applied to all the other secondary and intermediate beds by geognosts, who consult at the same time the position and mineral composition of rocks, far from overthrowing the whole system of formations already established, will rather serve to support, improve, and complete its vast series. The geognostic science of formations may, no doubt, be investigated under very different points of view, according as we give a preference to the superposition of mineral masses, to their composition (that is, their chemical and mineralogical analysis), or to the fossils which are contained in many of those masses; the whole of these are included in the science.... This unity of the science, and the vast field it comprehends, were well recognised by Werner, the founder of positive geognosy. Although he did not possess the necessary means for attaining a rigorous determination of fossil species, he never failed, in his course of lectures, to fix the attention of his pupils on the relations that exist between certain fossils and formations of different ages. I witnessed the high satisfaction that he felt, when M. de Schlottheim, one of the most distinguished geognosts of the school of Freiberg, began in 1792 to make those relations the principal object of his studies.[103]

[103]Humboldt, *Geognostical Essay*, 44, 66–67.

For the most part geognosts concentrated on the mineral-rich formations rather than the fossiliferous strata, and they worked in mines or in the field rather than in a museum equipped for comparative anatomy, but nevertheless (contrary to Cuvier's rhetorical pigeon-holing) they believed they were being true to a living and adaptive Wernerian geognostic tradition by incorporating Cuvier's use of fossil evidence.[104]

If we move beyond the agonistic horizons of the actors themselves and put to rest the demarcation debate, what comes into view is that Cuvier's demarcation rhetoric appears utterly conventional—a doing unto others only as they had already done to those who came before. Indeed, one is almost tempted to suggest, as an additional criterion for whether a given work is a Theory of the Earth, the severity with which it condemns previous Theories. Because of their multi-contextual nature, boundary work is a nearly constant occupation of textual traditions. Consider Jameson, one of the mineralogical Theorists from whom Rudwick is much concerned to dissociate Cuvier. Before his appropriation of Cuvier's work, Jameson already sharply distinguished Wernerian geognosy from Theories of the Earth based upon cabinet specimens rather than field evidence:

> We should form a very false conception of the Wernerian Geognosy, were we to believe it to have any resemblance to those *monstrosities* known under the name of *Theories of the Earth.* Almost all the compositions of this kind are idle speculations, contrived in the closet, and having no kind of resemblance to any thing in nature. Armed with all the *facts* and inferences contained in these visionary fabrics, what account would we be able to give of the mineralogy of a country, if required of us, or of the general relations of the great masses of which the globe is composed? Place one of these speculators in such a situation, and you will immediately discover the nature of his information, and he himself will find that he knows nothing; that he has been wandering in the mazes of error; and that, however *easily* he may have been able to explain the formation of this globe, and of the

[104]Humboldt's table of global formations from granite to gravel was included in later editions of Cuvier's Theory of the Earth; see Figure 8 on page 120. Only by regarding Wernerian geognosy in a considerably more narrow sense than did the historical actors themselves is it possible to treat it as an ossified, unchanging, strictly internalist tradition. Much more applicable is Laudan's description of it as an adaptive radiation; cf. "Geognosy and the Wernerian Adaptive Radiation," beginning on page 116. Lyellian caricatures of the Wernerian tradition are discussed below, page 330ff.

> whole universe, he cannot give a rational or satisfactory account of a single mountain.[105]

The factual vs. speculative dichotomy was not new; Jameson did to Theorists like Hutton what Cuvier did to Theorists like Jameson (and what Lyellians did to Theorists like Cuvier). Jameson's polemic here must be read as a defense of the techniques of geognosy for addressing questions raised in Theories of the Earth, not a repudiation of a properly-grounded Theory of the Earth for the sake of nothing but the facts. In the same way, Cuvier's similar rhetoric is best read as a defense of the techniques of comparative anatomy for addressing questions raised in Theories of the Earth, not a repudiation of the Theory of the Earth if properly grounded.[106] In a remarkable passage which is a classic formulation of an historical sensibility, Cuvier went so far as to claim that the Theory of the Earth becomes *possible* only when it constructs a historical sense of the past based entirely upon his preferred evidence:

> The importance of investigating the relations of extraneous fossils with the strata in which they are contained, is quite obvious. It is *to them alone* that we owe the *commencement even of a Theory of the Earth*; as, but for them, we could never have even suspected that there had existed any successive epochs in the formation of our earth, and a series of different and consecutive operations in reducing it to its present state. *By them alone* we are enabled to ascertain, with the utmost certainty, that our earth has not always been covered over by the same external crust;...[107]

The continuous debate, of course, was precisely over what kind of evidence was needed for the Theory of the Earth to become properly grounded, and discussions of the proper grounding

[105] Robert Jameson, *Elements of Geognosy,* vol. 3 of *System of Mineralogy: Comprehending Oryctognosie, Geognosie, Mineralogical Chemistry, Mineralogical Geography, and Oeconomical Mineralogy,* 3 vols. (Edinburgh, 1808); facsimile reprint Robert Jameson, *The Wernerian Theory of the Neptunian Origin of Rocks,* ed. Jessie M. Sweet (New York: Hafner Press, 1976), 42. On Jameson's Wernerianism as a Theory of the Earth see footnote 229 on page 123.

[106] In a notable passage concerned with Cuvier's early institutional relations Rudwick admits as much: "Cuvier's reluctance to be more explicit about his own conjectures was clearly related to what he saw as the disciplinary status of the various sciences. He was concerned above all to promote his own science of comparative anatomy, by showing that it was as rigorous as the physical sciences; if it was to be applied—in the matter of fossils—to the speculative area of 'geology' or 'theory of the earth,' the contrast had to be firmly established. Those disciplinary constraints could be relaxed, however, if he was not primarily addressing his colleagues." Rudwick, *Georges Cuvier*, 74.

[107] Cuvier, *Theory of the Earth* (1817), 54, italics added.

of Theories of the Earth inevitably raised controversial questions of natural order and historical contingency.

Theories of the Earth up to and including Cuvier's have been scorned as hotbeds of controversy nearly as much as they have been dismissed as indulgences in sheer speculation. Indeed, it is superficially tempting to recount their history as a dismal succession of fruitless controversies (Table 40). In an important article Roy Porter, one of the most notable scholars of British developments in the Earth sciences during the eighteenth century, characterizes the career of Theories of the Earth as "chequered," marked by constant feuding until they were finally and "ignominiously superseded" by geology at the turn of the nineteenth century.[108] These are strong words: according to one dictionary *ignominy* "stresses the almost unendurable contemptibility or despicability of the disgrace or its cause."[109] Contrary to Porter's writings as a whole, which are characterized by careful historical contextualization, these unguarded remarks reflect an unfortunately widespread sentiment that sound scientific practice proceeds only by consensus; that the indignity of controversy or the presence of satire signals that an endeavor is both moribund and pseudoscientific, outside the pale of legitimate natural knowledge.

The assumption that science is distinguished from nonscience by virtue of its ability to achieve consensus (and the corollary assumption that where consensus is not achieved the ethos of science is being violated) was broadly supported by mid-twentieth-century sociology of science, most notably in the distinguished work of Robert K. Merton. Merton's four *insti-*

[108] Roy Porter, "Creation and Credence: The Career of Theories of the Earth in Britain, 1660–1820," in *Natural Order: Historical Studies of Scientific Culture*, ed. Barry Barnes and Steven Shapin, 97–124 (Beverly Hills, CA: Sage Publications, 1979), 97–98: "... the main discussion—that is, why this scientific genre had such a chequered career. For theorists of the Earth were constantly feuding amongst themselves, and the discipline itself was to be ignominiously superseded by 'geology' at the turn of the 19th century. Why then was the theory of the Earth a failure as regulator of thought and action?" Cf. Roy S. Porter, *The Making of Geology: Earth Science in Britain, 1660–1815* (Cambridge: Cambridge University Press, 1977). Porter's analysis reveals some of the difficulties inherent in characterizing Theories of the Earth as a scientific discipline rather than as a textual tradition.

[109] *Webster's New Dictionary of Synonyms* (Springfield, Massachusetts: Merriam-Webster Inc., Publishers, 1984), s.v. "Disgrace," p. 253.

tutional norms defining the *ethos of science* aptly summarize what many working scientists take to be the case. They were concisely presented in Merton's essay on "The Normative Structure of Science" as

1. *Universalism*, that criteria of justification or validity are not subject to personal, ethnic, gender, workgroup, or national variations;
2. *Communism*, that science is a socially collaborative venture in which intellectual ownership and property is limited to peer recognition and esteem;
3. *Disinterestedness*, that peer review and rigorous self-policing maintain a virtual absence of fudging or fraud in science; and
4. *Organized Skepticism*, that scientists scrutinize all beliefs with detached judgment based solely on empirical and logical criteria.[110]

Merton's demarcationist norms are as plausible and seemingly applicable as Thomas Kuhn's description of the state of "normal science," but both Merton's norms and Kuhn's "normal science" are used to demarcate between science proper and pre-paradigmatic proto-science. That is, if there is controversy then the enterprise is at best pre-paradigmatic and protoscientific, by definition. Yet consensual normal science rarely exists so long as one broadens the context beyond a narrow circle of a single expert community; for this reason it is nearly always possible to deploy the lack of consensus as a rhetorical weapon against rivals to push them beyond the pale of science.[111] However, the demarcationist deployment of Merton's norms and Kuhn's paradigms is avoided with the analysis of technical traditions presented in Chapter 1. Technical traditions encompass the practice of consensual puzzle-solving techniques, yet still allow for occasions when scientists from different workgroups, disciplines, or technical

[110]Robert K. Merton, "The Normative Structure of Science," in *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago: University of Chicago Press, 1973), 267–278. A characterization of science as consensual public knowledge is extended along Mertonian lines in John M. Ziman, *Public Knowledge: An Essay Concerning the Social Dimension of Science* (Cambridge: Cambridge University Press, 1968); cf. footnote 161 on page 84.

[111]McEvoy's recent characterization of the history of chemistry applies equally well to most scientific disciplines: "What can be noted is that whatever episode in the long history of chemistry Brock is describing, the account is one of debate and disagreement, an incessant ferment of ideas, practices, personalities and institutions, a constant clash over fundamentals that is a far cry from the paradigmatic conformity of Kuhnian 'normal science.'" John G. McEvoy, *British Journal for the History of Science*, 1993, 26: 352, review of William H. Brock, *Norton History of Chemistry* (New York: W. W. Norton and Company, 1993). For early criticisms of Kuhn's deployment of normal science to demarcate science from protoscience, see Imre Lakatos and Alan Musgrave, eds., *Criticism and the Growth of Knowledge* (Cambridge: Cambridge University Press, 1970), especially the contributions by Popper, Watkins, and Toulmin.

traditions need to communicate across the boundaries of their tacit knowledge and technical competence—then controversy rather than consensus may be expected. For this reason post-Mertonian sociology of science has emphasized the significance of scientific controversies for the growth and development even of mainstream science, severely undermining any demarcational significance of Merton's norms more broadly applied.[112]

TABLE 40. Some prominent controversies in Theories of the Earth

Controversy	Description
Methodological considerations for Natural Philosophy: Authority, mysticism, reason, experiment.	Gilbert, Fludd (mysticism), Kepler (mathematical quantification), Descartes (mechanism), Steno (experiment and autopsia)
Decay of the Earth, Eternity of the World, or Perpetual Habitation?	
Origin of Extraneous Fossils	Extraneous fossils (or "figured stones") were found far from the ocean and made of stone (not animal material). Were they of organic origin? Or were they generated by natural processes of chemical transformation, such as the growth of seminal principles already present within the Earth?[a]
Origin of springs and rivers	
Ancients and Moderns[b]	Fontenelle, Keill
General and Particular Providence (role of miracles vs. natural law)	
Diluvialism I: Universal or regional Deluge	
Emplacement of organic fossils: deposition, internal circulation, transport	
Biological Transformism	
Plurality of Worlds	
Basalt Controversy	
Neptunism, Volcanism, Plutonism	
Defining characters of formations: mineral vs. fossil	
Diluvialism II: Recent superficial deposits (Buckland, English interpreters of Cuvier)	
Climatic trends	Ice Ages, Cooling contraction (Agassiz, Lyell)
Origin of Mountains	

a. The most sympathetic account of this episode is Martin J. S. Rudwick, The Meaning of Fossils: Episodes in the History of Palaeontology, 2d ed. (Chicago: University of Chicago Press, 1976).

b. See "Keill and the Local Intersection of Contested Textual Traditions," beginning on page 143.

Consistent with Mertonian characterizations of science as consensual knowledge, modern historians such as Rudwick and Porter disparage Theories of the Earth in the same way that many Theorists themselves disparaged other Theories of the Earth. Theorists of the Earth conceded nothing to contemporary satirists like Swift or Voltaire, for they ridiculed each other with a severity unsurpassed by writers outside the tradition (including historians). Theorists often went out of their way to explain that other Theories were not only mistaken in their conclusions, but undeserving of the dignity of being regarded as a proper endeavor of natural knowledge in the first place. For example, one early critic persuaded many to regard Burnet's Theory as a captivating romance rather than serious natural philosophy:

> These are the main foundations on which his Theory is built, and since I have proved them all to be not only precarious, but *impossible*, his whole Hypothesis must fall with them. Perhaps many of his Readers will be sorry to be undeceived, for as I believe, never any Book was fuller of Errors and Mistakes in Philosophy, so none ever abounded with more beautiful Scenes and surprising Images of Nature; but I write only to those who might perhaps to expect to find a true Philosophy in it. They who read it as an *Ingenious Romance* will still be pleased with their Entertainment.[113]

Burnet's writing was indeed eloquent, and some of his ideas repackaged positions already familiar to his readers from Ovid's *Metamorphoses* and Milton's *Paradise Lost*, such as that the axis of the paradisiacal Earth once was perpendicular to the plane of the ecliptic and thence had been knocked askew.[114] The accusation that a Theorist produced a fictional romance, to be enjoyed only as the fable of a poet, was a rhetorical trope of the Theory of the Earth tradition.[115]

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[112]The vast sociological literature on scientific controversies may be sampled in Michael Mulkay, "The Norms and Ideology of Science," *Social Science Information* 15 (1976): 637–656; S. B. Barnes and R. G. A. Dolby, "The Scientific Ethos: A Deviant Viewpoint," *Archives Européennes de Sociologie* 11 (1970): 3–25; R. G. A. Dolby, "Controversy and Consensus in the Growth of Scientific Knowledge," *Nature and System* 2 (1980): 199–218; and Harry M. Collins and Trevor Pinch, *The Golem: What Everyone Should Know about Science* (Cambridge: Cambridge University Press, 1993).

[113]John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698), 175–176; italics added.

[114]The tilting of the axis of the Earth after a primeval Golden Age was held by Milton and Burnet; Robert Hooke argued for a different notion of polar wandering which was also strenuously opposed by Keill. Cf. "Antiquity and Classical Learning," beginning on page 461; and "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354.

Similarly, with a sharpness equal to Jameson's dismissal of non-geognostic Theorists such as Hutton (page 319), Hutton himself denied that the views of mineralogists such as Werner (who was followed by Jameson) should even qualify as possible Theories of the Earth.[116] Hutton explained that Theories which did not measure up to his conception of a proper Theory were not Theories at all:

> Now, if I am to compare that which I have given as a theory of the earth, with the theories given by others under that denomination, I find so little familiarity, in the things to be compared, that no other judgment could hence be formed, perhaps, than that they had little or no resemblance. I see certain treatises named Theories of the Earth; but, I find not any thing that entitles them to be considered as such, unless it be their endeavouring to explain certain appearances which are observed in the earth. That a proper theory of the earth should explain all those appearances is true; but, it does not hold, conversely, that the explanation of an appearance should constitute a theory of the earth. So far as the theory of the earth shall be considered as the philosophy or physical knowledge of this world, that is to say, a general view of the means by which the end or purpose is attained, nothing can be properly esteemed such a theory unless it lead, in some degree, to the forming of that general view of things.[117]

Burnet, the first Theorist Hutton considered, invoked evidence from scripture and classical antiquities which Hutton regarded as no more reliable than a poetic fable: "This surely cannot be considered in any other light than as a dream, formed upon the poetic fiction of a golden age."[118] In contrast, Maillet's *Telliamed* relied not only upon antiquities but also upon careful geological observations. However, more important than types of evidence, for Hutton, was the ahistorical sensibility of Maillet's system: "This is a theory which has *something*

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[115]It was a common trope with an ancient literary pedigree: Aristotle dismissed the geological views of Empedokles, who wrote in hexameter verse, as merely poetic metaphor. (*Meteorology* 357a24-28). Moreover, Lloyd observes, Aristotle denounced Empedokles even on poetic grounds; *Poetics* 1447b17-18, Geoffrey Ernest Richard Lloyd, *Demystifying Mentalities, Themes in the Social Sciences* (Cambridge: Cambridge University Press, 1990), 23. And Cicero proclaimed that "These are fables of the poets, whereas we aim at being philosophers, who set down facts, not fictions." *De natura deorum*, III.xxxi.77; Cicero, *De natura deorum, Academica*, trans. H. Rackham, Loeb Classical Library, no. 268 (Cambridge: Harvard University Press; London: Heinemann, 1933), 363. Burnet used the very same rhetorical distinction; see footnote 7 on page 435 and the discussion on page 624 ff. Of course, this trope also is relevant to the manner in which D'Alembert "complimented" Buffon's style; footnote 196 on page 108.

[116]See page 710, and Cuvier's similar proscription on page 320.

[117]Hutton, *Theory of the Earth* (1795), 1: 270; emphasis added.

[118]Hutton, *Theory of the Earth* (1795), 1: 271.

in it like a regular system, such as we might expect to find in nature; but, it is only a physical romance, and cannot be considered in a serious view, although apparently better founded than most of that which has been wrote upon the subject."[119] Buffon, on the other hand, produced a "theory of a very different kind," a directionalist history of the Earth composed of a series of particular events which, in Hutton's view, amounted to creation by accident rather than the deity's wise contrivance of a permanently habitable world:

> Here is a theory, not founded on any regular system, but upon an irregularity of nature, or an accident supposed to have happened to the sun.... But, *are we to consider as a theory of the earth, an accident* by which a planetary body had been made to increase the number of these in the solar system? The circumvolution of a planetary body (allowing it to have happened in that manner) cannot form the system of a world, such as our earth exhibits; and, in forming a theory of the earth, it is required to see the aptitude of every part of this complicated machine to fulfil the purpose of its intention, and not to suppose the wise system of this world to have arisen from the cooling of a lump of melted matter which had belonged to another body. When we consider the power and wisdom that must have been exerted, in the contriving, creating, and maintaining this living world which sustains such a variety of plants and animals, the revolution of a mass of dead matter according to the laws of projectiles, although in perfect wisdom, is but like a unite [*sic*] among an infinite series of ascending numbers.[120]

Hutton concluded that Buffon's system was "founded on a mere accident, or rather the error of a comet which produced the beautiful system of this world..."[121] As a final example, Hutton regarded Deluc's more recent Theory as similarly marred because, despite the fact that it privileged geological observations like Maillet's, nevertheless like Buffon's it propounded a directionalist and contingent history rather than a stable and habitable world existing as the product of intelligent design:

> [Deluc] has given us the *history of a disaster* which befel this well contrived world; —a disaster which caused the general deluge, and which, without a miracle, must have undone a system of living beings that are so well adapted to the present state of things. But, surely, general deluges *form no part of the theory of the earth*; for, the

[119]Hutton, *Theory of the Earth* (1795), 1: 271; italics added.

[120]Hutton, *Theory of the Earth* (1795), 1: 271–2; italics added.

[121]Hutton, *Theory of the Earth* (1795), 1: 272.

> purpose of this earth is evidently to maintain vegetable and animal life, and not to destroy them.[122]

John Playfair therefore expressed a profoundly Huttonian sentiment when he featured a quotation from Seneca on the frontispiece of his *Illustrations of the Huttonian Theory of the Earth*: "Nunc naturalem causam quaerimus et assiduam, non raram et fortuitam."[123] Despite Hutton's demarcation attempt, few modern historians dispute the fact that Burnet, Maillet, Buffon, Werner or Deluc were Theorists of the Earth in some meaningful historical sense.[124] While it would be misguided for a historian to take boundary work and demarcation rhetoric at face value by siding with one historical actor against another, upon a second glance rhetorical contests bring to light interesting facets of the textual tradition and its actors that otherwise remain more obscure. In general these disputes reflect the character of Theories of the Earth as a public forum for debating the roles of natural order and historical contingency in different visions of the Earth's past. In this case both Hutton and Cuvier asserted that only those Theories which relied primarily upon their favored type of evidence should even qualify as possible Theories of the Earth. It is manifest that Hutton's deistic, nondirectionalist teleology not only shaped his views on particular topics, but also constrained even what he would allow in principle as acceptable theorizing. And Cuvier's demarcation rhetoric reflects the significance which he attached to his institutional advantages and unequalled expertise in comparative anatomy.

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[122]Hutton, *Theory of the Earth* (1795), 1: 273; italics added. Given Hutton's rejection of contingency, the same criticism Hutton directed toward Deluc should apply equally from his vantage point to Cuvier's Theory as a "history of disasters."

[123]John Playfair, *Illustrations of the Huttonian Theory of the Earth* (Edinburgh: for Cadell and Davies, London, and William Creech, Edinburgh, 1802). Cf. Seneca, *Natural Questions* II, 55.3: "We are now seeking the natural and usual cause, not the rare and accidental," Lucius Annaeus Seneca, *Naturales Quaestiones*, trans. Thomas H. Corcoran, vol. 1, 2 vols., Loeb Classical Library, no. 450 (Cambridge: Harvard University Press; London: Heinemann, 1971), 186–187.

[124]Note that Hutton's demarcation attempt is the exact contrary of Roger's directionalist criterion; see above, page 211. The plague of partial and conflicting definitions falls on both houses: Maillet and Hutton, whose works were universally regarded as Theories of the Earth, should by themselves refute Roger's deployment of an essential directionalist criterion, while Roger's own erudition (and Cuvier's quote on page 320) should refute Hutton's contrary deployment of an essential nondirectionalist criterion.

For these reasons, controversy in a contested textual tradition is neither unexpected nor pathological. The mere existence of ignominious quarrels involving Theories of the Earth does not render the textual tradition chequered any more than Twain's satire of nineteenth-century Mississippi River geologists renders the glory days of historical geology suspect.[125] Early geologists were determined to distance themselves from the later Theorists for a variety of reasons, just as Theorists had already sought to distinguish themselves from each other. Similarly, later geologists sought to distance themselves from earlier geologists, to the extent that geology today is less perceived as immune from controversy than as almost characterized by it, marked by a past as chequered as that of the Theorists themselves. Nineteenth-century geological controversies followed one another with unabated frequency, including Louis Agassiz's crusade for global ice sheets and the existence of past Ice Ages; disputes over the relative stratigraphical importance of fossils vs. mineral characters in the Cambrian-Silurian controversy and the Devonian controversy; controversies over the origin of mountains and the structure of the Alps and Scottish Highlands; controversies about the age of the Earth or whether the Earth is cooling and how it might be contracting, as well as the degree to which conclusions in physics and cosmology should function as constraints upon geological theorizing. Each of these debates extended discussions previously engaged in Theories of the Earth.[126] In the twentieth century there have been intense and passionate debates over J Harlan Bretz's interpretation of the Great Scablands; Alfred Wegener's theory of continental drift; Warren

[125] Mark Twain, *Life on the Mississippi,* chapter XVII: "Now, if I wanted to be one of those ponderous scientific people, and 'let on' to prove what had occurred in a given time in the recent past, or what will occur in the far future by what has occurred in the late years, what an opportunity is here! Geology never had such a chance, nor such exact data to argue from! Nor 'development of species,' either! Glacial epochs are great things, but they are vague—vague. Please observe:— In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. This is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oolithic Silurian Period, just a million years ago next November, the Lower Mississippi River was upwards of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact."

Carey's theory of an expanding Earth; plate tectonics; and asteroid-impact hypotheses to explain mass-extinction events and the death of dinosaurs. Even current doomsday scenarios of global warming, mineral-resource depletion and overpopulation are not without their Swift-like critics.[127]

In these controversies of modern geology, protagonists accuse each other not merely of being mistaken, but of failing to remain within the proper bounds of science. Particularly when the controversies involve practitioners of multiple disciplines, such as geophysicists vs. historical geologists, physicists vs. geologists, or (still worse) natural scientists vs. economists, acrid controversies are still sometimes played out before a watching public.[128] For example,

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[126]Many of these and the following episodes are treated in Anthony Hallam, *Great Geological Controversies*, 2d ed. (Oxford: Oxford University Press, 1989). On Agassiz and Ice Age controversies see John Imbrie and Katherine Palmer Imbrie, *Ice Ages: Solving the Mystery* (Cambridge: Harvard University Press, 1979). On fossil vs. mineralogical criteria see James A. Secord, *Controversy in Victorian Geology: The Cambrian-Silurian Dispute* (Princeton: Princeton University Press, 1986). On other stratigraphical controversies see Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985) and David R. Oldroyd, *The Highlands Controversy: Constructing Geological Knowledge through Fieldwork in Nineteenth-Century Britain*, ed. (Chicago: Chicago University Press, 1990). On the origin of mountains, the Alps, global contraction, and global tectonics see Mott T. Greene, *Geology in the Nineteenth Century: Changing Views of a Changing World*, Cornell History of Science Series (Ithaca: Cornell University Press, 1982). On the age of the Earth and physical constraints on geological inference see Joe D. Burchfield, *Lord Kelvin and the Age of the Earth* (New York: Science History, 1975; reprinted with a new afterword, Chicago: University of Chicago Press, 1990), and also Philip J. Lawrence, "Heaven and Earth—The Relation of the Nebular Hypothesis to Geology," in *Cosmology, History, and Theology*, ed. Wolfgang Yourgrau and Allen D. Beck, 253–281 (New York: Plenum Press, 1977). A well-known controversy with no obvious tie to Theories of the Earth were the dinosaur rivalries recounted in Mark Jaffe, *The Gilded Dinosaur: The Fossil War between E. D. Cope and O. C. Marsh and the Rise of American Science* (New York: Crown Publishers, 2000).

[127]"J" is spelled without a period. On the Great Scablands see Stephen Jay Gould, "The Great Scablands Debate," in *The Panda's Thumb: More Reflections in Natural History* (New York: W. W. Norton and Company, 1980), 194–203; and Victor R. Baker, "The Spokane Flood Controversy and the Martian Outflow Channels," *Science* 202 (1978): 1249–1256. The Scablands and other geological controversies are surveyed by E. K. Peters, *No Stone Unturned: Reasoning about Rocks and Fossils* (New York: W. H. Freeman and Company, 1996). On Wegener, continental drift and plate tectonics see Homer E. Le Grand, *Drifting Continents and Shifting Theories: The Modern Revolution in Geology and Scientific Change* (Cambridge: Cambridge University Press, 1988) and Naomi Oreskes, *The Rejection of Continental Drift: Theory and Method in American Earth Science* (Oxford: Oxford University Press, 1999. On the idea of an expanding Earth see S. Warren Carey, *Theories of the Earth and Universe: A History of Dogma in the Earth Sciences* (Stanford: Stanford University Press, 1988). For an insider's account of the asteroid-impact controversy as unconventional science, see David M. Raup, *The Nemesis Affair: A Story of the Death of Dinosaurs and the Ways of Science* (New York: W. W. Norton and Company, 1986). A sequel to this book is David M. Raup, *Extinction: Bad Genes or Bad Luck?* (New York: W. W. Norton and Company, 1991). A recent defense by one of the original proponents is Walter Alvarez, *T. Rex and the Crater of Doom* (New York: Vintage Books, Random House, 1997); a recent dissenting view is Charles Officer and Jake Page, *The Great Dinosaur Extinction Controversy* (Reading, Massachusetts: Addison-Wesley Publishing Company, 1996). Cf. William Glen, ed., *The Mass-Extinction Debates: How Science Works in a Crisis* (Stanford: Stanford University Press, 1994), and comments introducing Whiston above, page 297. A economist critic of doomsday scenarios of resource depletion is Julian Simon, *The Ultimate Resource*, 2d ed. (Princeton: Princeton University Press, 1996).

in the 1940's the geologist Bailey Willis criticized Wegener's theory of continental drift not as wrong, but as *impossible*:

> I confess that my reason refuses to consider 'continental drift' possible.... further discussion of it merely incumbers the literature and befogs the mind of fellow students.... Fellow scientists who are not geologists cannot be expected to know that the geology upon which protagonists of the theory rest assumptions is as antiquated as pre-Curie physics. Wegener and his successors are disciples of Eduard Suess, the Master of European geologists. I knew him well: a charming, genial German, who never travelled far, but assembled the observations of others and from them constructed speculations regarding the face of the Earth. His reading was prodigious, his memory marvellous, his imagination grand; but he gravely lacked critical faculty. And when some airy concept had grown in his mind, it became too firmly rooted ever to be dislodged. Such a concept was Gondwana Land, the continent supposed to have extended from the East Indies westward to the Pacific, embracing India, Africa and South America and occupying the sites of the Indian and South Atlantic Oceans.... Thus the theory of continental drift is a fairy tale, *ein Märchen*. It is a fascinating fancy which has captured imaginations.[129]

Many of the rhetorical elements usually targeted toward Theories of the Earth are here displayed against continental drift. Drift theorists exercise great imagination, indulge in speculation, and produce captivating fairy tales. Once they hit on a charming idea they never let it go, no matter what evidence surfaces to the contrary. Their book-knowledge may be immense, but their direct experience is provincial. Their geological methods are antiquated. And most interestingly, they are caricatured by their intellectual genealogy, by their alleged conformity to outdated predecessors: Wegener's followers in the first half of the twentieth century are dismissed as under the sway of a foreigner who published his work half a century before.

The paradigmatic rhetoric of demarcation is Lyell's caricature of Werner, the founder of the geognosy practiced by many geologists contemporary with Lyell, particularly on the conti-

[128]For example, as the dinosaur extinction controversy was developing, a *New York Times* editor entered the fray against the impact theorists, asserting that "Astronomers should leave to astrologers the task of seeking the cause of earthly events in the stars." *New York Times*, Tuesday, April 2, 1985. Reprinted in M. Raup, *The Nemesis Affair: A Story of the Death of Dinosaurs and the Ways of Science* (New York: W. W. Norton and Company, 1986), 174.

[129]Bailey Willis, *American Journal of Science*, 1943, 549.

nent. Lyell informed his readers that Werner exercised great imagination, indulged in speculation, and produced captivating fairy tales. Once he hit on a charming idea neither he nor his pupils ever let it go, no matter what evidence surfaced to the contrary:

> Werner by his dictum caused a retrograde movement, and not only overturned the true theory, but substituted for it one of the most unphilosophical ever advanced in any science. The continued ascendancy of his dogmas on this subject was the more astonishing, because a variety of new and striking facts were daily accumulated in favour of the correct opinions first established.[130]

His book-knowledge was immense, but his direct experience was provincial:

> Werner had never travelled to distant countries. He had merely explored a small portion of Germany, and conceived, and persuaded others to believe, that the whole surface of our planet, and all the mountain chains in the world, were made after the model of his own province.[131]

And most interestingly, Werner's followers in the first half of the nineteenth century were dismissed as under the sway of a charismatic foreigner who published his work half a century before:

> In opposition to this mass of evidence, the scholars of Werner were prepared to support his opinions to their utmost extent, maintaining in the fulness of their faith that even obsidian was an aqueous precipitate. As they were blinded by their veneration for the great teacher, they were impatient of opposition, and soon imbibed the spirit of a faction.... Ridicule and irony were weapons more frequently employed than argument... till at last the controversy was carried on with a degree of bitterness, almost unprecedented in questions of physical science.[132]

Lyell, himself a master of irony and ridicule, deployed such anti-Wernerian rhetoric to defend his own controversial geological principles.[133]

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[130] Charles Lyell, *Principles of Geology* (1830), 59; cf. p. 57: "It was a ruling object of ambition in the minds of his pupils to confirm the generalizations of their great master."

[131] Charles Lyell, *Principles of Geology* (1830), 57.

[132] Charles Lyell, *Principles of Geology* (1830), 60.

[133] Lyell's distortion of Werner is analyzed by Alexander M. Ospovat, "The Distortion of Werner in Lyell's Principles of Geology," *British Journal for the History of Science* 9 (1976): 190–198. For a correction to Lyellian interpretations of Werner's influence see footnote 103 on page 318.

Despite the evident unjustness of Lyell's account of the development of geology, the historiographical point is that the existence of controversy is not a reliable indicator of "pathological science,"[134] nor is controversy a sign of the failure of a tradition to "regulate thought and action."[135] *Pace* Merton, controversy often characterizes frontier science, particularly when it involves multidisciplinary discourse. *Pace* conventional interpretations, the existence of controversy in modern geology and between advocates of rival Theories of the Earth may signal vigorous growth and rapid development in new investigative directions (particularly those which involve novel sources of evidence).

While the reception of any particular Theory of the Earth may well have seemed ignominious to some, in its own setting there were usually others who found it eminently attractive and compelling for guiding further investigation. Nearly thirty years before Lyell in a book remarkable for its irenic tone, John Murray compared the Huttonian system with the Wernerian and found the Huttonian wanting, but nevertheless argued for the fruitfulness of theoretical debate:

> Systems, says a geological writer, are in the sciences what the passions are in the human mind: they may be the source of great errors, but they are the cause also of great exertions. Either in defending or opposing them, it is necessary to observe with accuracy, to compare and generalise; objects apparently minute, acquire an interest and importance; views are suggested which often lead to real acquisitions; facts are arranged which would have remained isolated; and relations traced which would not have been observed.[136]

Despite his keen sensitivity to the dangers of overcommitment to a particular theory, Henry Thomas de la Beche (1796-1855) wrote of a later controversy in early historical geology, concluding:

[134]Pathological science was Irving Langmuir's term, invented to explain the N-ray affair.

[135]As quoted in footnote 108 on page 321.

[136]John C. Murray, *A Comparative View of the Huttonian and Neptunian Systems of Geology, in answer to the Illustrations of the Huttonian Theory of the Earth, by Professor Playfair* (Edinburgh: Printed for Ross and Blackwood...; and T. N. Longman, and O. Rees, London, 1802), v.

> That much good ensues, and that the science is greatly advanced, by the collision of various theories, cannot be doubted. Each party is anxious to support opinions by facts. Thus, new countries are explored, and old districts re-examined; facts come to light that do not suit either party; new theories spring up; and in the end, a greater insight into the real structure of the earth's surface is obtained.[137]

Theorists frequently voiced similar sentiments.[138] At best, in Theories of the Earth as in geology, the existence of controversies, the collision of theories, suggests the lively growth of vigorous research traditions communicating in a public forum such as a contested textual tradition.

Demarcation attempts—whether Cuvier's, Hutton's, or Lyell's—are constitutive of vigorous, dynamically-changing traditions. One sign of a dying tradition would be the lack of controversies with attending demarcation debates.[139] Demarcation attempts are inherently rhetorical endeavors which at best foster critical debate within the tradition and contribute to its transformation.[140] One of the key measures of the health of the Theory of the Earth tradition at any given time, then, is not so much the presence of controversy as the degree to which

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[137]Henry Thomas de la Beche, *Sections and Views Illustrative of Geological Phenomena* (London: Treuttel & Würtz, 1830), p. iii. On the same page De la Beche wryly suggested: "Theories, no doubt, are useful to a certain extent, for they promote inquiry; and, in the present day, a few facts, at least, must be brought forward to support them." The immediate context of these remarks consists of sarcastic barbs about the inadequate factual basis of earlier Theories of the Earth, in contrast to de la Beche's more objective observations: "The following sections and views are not intended to support or oppose any particular theory: the sole object in collecting them together has been utility," iii (compare the rhetoric of William Phillips, page 351). Yet any satirical barbs directed toward Theories of the Earth by de la Beche must be read in part as rhetorical self-defense, for de la Beche continued (vii): "I may, doubtless, be accused of having indulged in theoretical speculations in the explanations of the following Plates. I have endeavoured to guard myself against this pleasure,—for pleasure it is,—but perhaps have not been always very successful." In fact, global sections and views rose to prominence in Theories of the Earth, as will be shown in Part II, an association which may have contributed to his anxiety to be distinguished in the minds of his readers from the tradition. Cf. de la Beche's illustrations in the last row of Table 26, "Correspondence of Global and Local illustrations," on page 215.

[138]For example, an American Theorist defended his hexamerally-organized contribution on these grounds: "Though systems of geology almost without number have been sent forth into the world, some of which darken more than they enlighten the mind, and instead of guiding the votaries of science to the temple of truth, bewilder them in the labyrinth of error, yet most of the theories have been useful. They have excited the human mind to inquiries, induced many to enter the extensive field of research, and have been the cause of many important discoveries." Typically, Hill also insisted that his own Theory was "formed from observation" and based on facts. Ira Hill, *An Abstract of a New Theory of the Formation of the Earth* (Baltimore: Published by N. G. Maxwell, 1823), xiii. See also the quote by Playfair in footnote 99 on page 54.

[139]"We are apt to be misled here by the ideological uses to which the concept of a tradition has been put by conservative political theorists. Characteristically such theorists have followed Burke in contrasting tradition with reason and the stability of tradition with conflict. Both contrasts obfuscate. For all reasoning takes place within the context of some traditional mode of thought, transcending through criticism and invention the limitations of what had hitherto been reasoned in that tradition; this is as true of modern physics as of medieval logic." Alasdair MacIntyre, *After Virtue: A Study in Moral Theory*, 2d ed., vol. 1 (South Bend: Notre Dame University Press, 1984), 221–222; hereafter, MacIntyre, *After Virtue*.

relevant evidence from new lines of inquiry was recognized, developed, sought after, and appropriated by various Theorists.[141] To the extent that this was the case (and it often was) the tradition provided a discursive space for its own transformation, in the process helping to shape various temporal sensibilities and to catalyze the differentiation of specific technical disciplines.

In an off-hand remark, one acute interpreter of eighteenth-century Earth sciences dismissed the significance of Theories of the Earth on the basis of their allegedly nonsocial, individual character:

> if we take collective work to be the characteristic trait of science, these theories belong, at best, at the threshold of this history [of geology] because the phrase 'theory of the earth' really only describes an individual work—each author's own theory.[142]

Yet traditions—textual as well as technical—are collective social endeavors. The point is not that Theorists disagreed on an isolated, individual basis, but that the tradition constituted an arena before the professionalization of geology for public negotiation on divisive issues, including the key question of what would count as decisive evidence. To describe Theories of the Earth as a *contested tradition* emphasizes the social and collective character of textual debate. The valid contrast to be made with technical traditions such as geology is not the existence of controversy, but that on occasion geologists succeeded in confining their controversies to arenas where technical experts might resolve them, as in the closed-door oral debates

[140] "When a tradition is in good order it is always partially constituted by an argument about the goods the pursuit of which gives to that tradition its particular point and purpose. So when an institution—a university, say, or a farm, or a hospital—is the bearer of a tradition of practice or practices, its common life will be partly, but in a centrally important way, constituted by a continuous argument as to what a university is and ought to be or what good farming is or what good medicine is. Traditions, when vital, embody continuities of conflict. Indeed, when a tradition becomes Burkean, it is always dying or dead." MacIntyre concludes: "A living tradition then is an historically extended, socially embodied argument, and an argument precisely in part about the goods which constitute that tradition." MacIntyre, *After Virtue*, 222.

[141] "Traditions decay, disintegrate and disappear. What then sustains and strengthens traditions? What weakens and destroys them? The answer in key part is: the exercise or the lack of exercise of the relevant virtues.... Lack of justice, lack of truthfulness, lack of courage, lack of the relevant intellectual virtues—these corrupt traditions, just as they do those institutions and practices which derive their life from the traditions of which they are the contemporary embodiments." MacIntyre, *After Virtue*, 222–223.

[142] Gabriel Gohau, *A History of Geology*, 2.

of the Geological Society of London (and earlier, to some extent, among the members of *l'Académie Royale des Sciences*[143]). Theories of the Earth were a textual tradition displaying and carrying on their controversies in a wider public sphere. The alleged demise of Theories of the Earth was attendant upon the gradual eighteenth-century differentiation of natural philosophy and natural history into technical scientific disciplines, and upon the professionalization of those technical fields in the nineteenth century. Rather than a transcending of subjective controversy by the establishment of consensual science, the transformation of Theories of the Earth is better described as a transfer from a textual tradition into a set of technical disciplines of the social processes for resolving controversies.[144]

§ 6. Marginality and Mentalité

Noting the contested nature of the Theory of the Earth tradition and assuming that it came to an abrupt demise at the end of the eighteenth century, Roy Porter addresses the chief question of "Why then was the theory of the Earth a failure as regulator of thought and action?"[145] Porter insists that "The question cannot be ducked." Forthrightly anticipating

[143]Rappaport argues for the importance of giving historical attention to Fontenelle's summaries of the technical papers published in the Academy's *Mémoires*, since Fontenelle "used the forum of the *Histoire* to communicate with the non-specialist and to place narrow, technical articles into larger contexts." Therefore, "the *Histoire*, at least in Fontenelle's day, ought to be studied as a vehicle for the dissemination of ideas only obliquely visible in the pages of the *Mémoires*." Rhoda Rappaport, "Fontenelle Interprets the Earth's History," *Revue d'Histoire des Sciences* 44 (1991): 299–300. Given this analysis, it might be suggested that Fontenelle's articles collectively comprise a Theory of the Earth or something like it in the relatively textual tradition of the *Histoires*. Rappaport's study throws great light on the contemporary contexts for articles published in the relatively technical tradition of the *Mémoires*.

[144]Rudwick cites the description of Geological Society meetings by John Lockhart, editor of the *Quarterly Review*: "Though I don't care much for geology, I do like to see the fellows fight." Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), 25. Cf. "Textual versus Technical Traditions," beginning on page 79.

[145]Porter, "Creation and Credence," 98; passage quoted in full in footnote 108 on page 321. Porter cites Collier and Roger for the claim that Theories of the Earth came to an abrupt demise, yet this claim is problematic in part because Collier and Roger used different (overlapping) definitions of Theories of the Earth and discussed different (overlapping) populations of actors. Cf. Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries* (New York: Columbia University Press, 1934; reprinted New York: Octagon Books, 1968); and Jacques Roger, "La théorie de la terre au XVIIe siècle," *Revue d'Histoire des Sciences* 26 (1973): 23–48. Collier and Roger are discussed above in Chapter 2.

that he may be charged with presentism for formulating the historical problem this way, he continues: "To pose it is not Whiggishly to dismiss such theories as stupid, but to point out that they did not successfully establish and sustain themselves."[146] Such an argument, though not Whiggish, amounts to a "Marginality Thesis" regarding the significance of Theories of the Earth both in their original context and for the development of later geology.[147]

§ 6-i. Marginality Thesis – Pro

Setting Porter's particular remarks aside; in general, to support any such Marginality Thesis, a case might be made that Theories of the Earth were marginal because:

1. they were opposed and displaced by later geologists;
2. they were excluded from geological societies and treatises;
3. the problems they addressed became of little or no lasting interest;
4. they were predominantly theoretical and speculative;
5. they therefore lacked any means for self-correction and sustained improvement; and
6. they were widely recognized as moribund and summarily consigned to an abrupt oblivion in the early nineteenth century.

How might these claims be supported in defense of a Marginality Thesis? Evidence in their favor may be found by perusing Benoît de Maillet's *Telliamed, or Conversations Between an Indian Philosopher and a French Missionary on the Diminution of the Sea, the Formation of the Earth, the Origin of Men and Animals*, written around 1729 and circulated in manuscript until a less-outrageous redaction was published at mid-century.[148]

First, the *Telliamed* was opposed and displaced by later geologists who rejected its arguments for the eternity of the Earth. Maillet's arguments were based upon such evidential

[146]Porter, "Creation and Credence," 98; passage quoted in full in footnote 108 on page 321.

[147]Porter rightly defends his claim from the charge of Whiggism, which targets positivist views of cumulative development. The desire to avoid Whiggism does not entail an epistemological relativism, nor does it necessarily commit one to refraining from judgments regarding the fruitfulness of research programs (see the caveat before the quotation from Butterfield in footnote 14 on page 270). Although I disagree with Porter's claim that Theories of the Earth were not successful, this is primarily an empirical rather than historiographical matter. The historiographical point of this section regards unrecognized problems inherent in a Marginality Thesis; it has nothing to do with Whiggism.

grounds as metaphysical and philosophical reasoning,[149] Chinese chronologies, and inferences from cyclic processes observed on the shores of the Mediterranean.

Second, the *Telliamed* was clandestinely circulated without a trace of solemn scientific authority: it was written in a dialogue form (the fictional Indian philosopher's name is Maillet spelled backward). A more fanciful piece of writing is hard to find; the editor dedicated it to Cyrano de Bergerac (1619–1655), author of *Voyages to the Sun and Moon*—a fantasy satirizing French society which Nicolson called "the most brilliant of all seventeenth-century parodies of the cosmic voyage."[150]

Third, many of the problems the *Telliamed* addressed were of little or no lasting interest. For example, some were occasioned by his Neoplatonic appropriation of Cartesian cosmology, elaborated into his own cyclic vision in which the Sun is now being consumed in a cosmic circulation of fire and life-spirit:

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[148] Maillet's work was finally published in Amsterdam in 1748, with numerous subsequent French editions; an English translation followed in 1750, with an American edition in 1797. Cf. Benoît de Maillet, *Telliamed, ou Entretiens d'un Philosophe Indien avec un Missionnaire François Sur la Diminution de la Mer, la Formation de la Terre, l'Origine de l'Homme, &c, Mis en ordre sur les Mémoires de feu M. de Maillet Par J. A. G****, 2 vols. (Amsterdam: Chez L'honoré & Fils, Libraires, 1748); Benoît de Maillet, *Telliamed: or, Discourses Between an Indian Philosopher and a French Missionary, on the Diminution of the Sea, the Formation of the Earth, the Origin of Men and Animals, and other Curious Subjects relating to Natural History and Philosophy* (London: Printed for T. Osborne, 1750); and Benoît de Maillet, *Telliamed; or, The World Explain'd: Containing Discourses between an Indian Philosopher and a Missionary, on the Diminution of the Sea, the Formation of the Earth, the Origin of Men & Animals, and other Singular Subjects relating to Natural History & Philosophy* (Baltimore: Printed by W. Pechin . . . for D. Porter, 1797). An accessible translation with introduction, notes and publishing history is Benoît de Maillet, *Telliamed: Or Conversations Between an Indian Philosopher and a French Missionary on the Diminution of the Sea*, trans. and ed. Albert V. Carozzi (Urbana: University of Illinois Press, 1968); hereafter Carozzi, *Telliamed*. Several careful studies of Maillet have been published by Cohen; cf. Claudine Cohen, "Benoît de Maillet et la diffusion de l'histoire naturelle à l'aube des lumières," *Revue d'Histoire des Sciences* 44 (1991): 325–342; and Claudine Cohen, "Les Métamorphoses de Telliamed," *Corpus: Revue de Philosophie* (1985): 62–73.

[149] For example, Maillet argued that matter cannot be annihilated and is therefore eternal, because a reasonable God must have created from all eternity. Carozzi, *Telliamed*, 161.

[150] Marjorie Hope Nicolson, *Voyages to the Moon* (New York: MacMillan, 1948), 159. Cyrano de Bergerac was a student of Gassendi and a friend of the Cartesian Jacques Rohault (1620–1675). Like Rohault's immensely popular *Traité de Physique* (1671), Bergerac's fragmentary *Traité de physique* is largely Cartesian (according to Strachan); cf. Savinien Cyrano de Bergerac, *L'Autre Monde ou Les États et Empires de la Lune*, ed. Madeleine Alcover (1650; Paris: Librairie Honoré Champion, 1977); Savinien Cyrano de Bergerac, *Other Worlds: The Comical History of the States and Empires of the Moon and the Sun*, trans. Geoffrey Strachan (Oxford: Oxford University Press, 1965); and Mary Baine Campbell, *Wonder and Science: Imagining Worlds in Early Modern Europe* (Ithaca: Cornell University Press, 1999). The *Voyages to the Sun and Moon* were circulated clandestinely before posthumous publication. On Maillet and clandestine literature see Miguel Benitez, "Benoît de Maillet et la Littérature Clandestine: Étude de sa Correspondance avec l'Abbé Le Mascrier," *Studies on Voltaire and the Eighteenth Century* 183 (1980): 133–159.

> The passage of fire from one globe to another where it is smothered, a certain spirit of life transmitted in the same manner, the return of that same spirit to the first globe after having been lost by the second, are endlessly repeated vicissitudes which represent a kind of circulation as real as that of blood in our veins. This large-scale circulation which generates smaller ones is responsible for maintaining the universal soul of the world from which our souls emanate and what alive is animated. It is responsible for the immortality of our souls, the perpetuity of movement, and finally the eternity of the world which is the representation of God himself.[151]

Fourth, a case that the *Telliamed* was predominantly theoretical and speculative could point to its uncritical acceptance of mermaids and other suspect "observations."[152] Petrified human bones and a ship found in a Swiss iron mine were reported to provide empirical support for an ancient Earth. The writer optimistically asked: "Would it be absurd to believe that the sea elephant [elephant seal, with two long tusks] originated the species of land elephants?"[153] All animals arose, we are assured, from analogous forms in the sea; for example, birds originated from flying fish. That sea dogs, sea wolves, mermen and mermaids produced analogous terrestrial forms is buttressed by an account of a seagirl caught in the Zuider Zee who married a Dutchman and lived happily ever after, yet exhibited a special fondness for gazing upon canals and rivers. Historical records and folk traditions are said to bolster claims of indigenous origin from the sea, and of men who could fly.[154]

[151] Carozzi, *Telliamed*, 233. Maillet drew a microcosm-macrocosm parallel with the circulation of blood: "my system, dealing actually with another kind of circulation...."

[152] Carozzi, *Telliamed*, 122.

[153] Carozzi, *Telliamed*, 189.

[154] The woman of the Zuider Zee is related in Carozzi, *Telliamed*, 193. On folk science see "Textual versus Technical Traditions," beginning on page 79. Cf. Miguel Benitez, "Benoît de Maillet et l'Origine de la Vie dans la Mer: Conjecture Amusante ou Hypothèse Scientifique?" *Revue de Synthèse* 105 (1984): 37–54.

§ 6-ii. Marginality Thesis – Contra

Despite the case just sketched, one can make a strong argument that for two centuries Theories of the Earth were not marginal, but sustained themselves as a textual tradition in which experts participated from a variety of technical discourses. The same example of Maillet refutes several stereotypes of the tradition for, despite its flights of speculation,[155] the cosmological vision of the *Telliamed* implied that the age of the Earth was immense. Maillet suggested that after as much as two billion years a given star would burn out and become a planet. Then the planet, covered by an ever-diminishing quantity of water, would undergo a long period of drying out. On the basis of historical reports and first-hand measurements of the advance of the shoreline, Maillet estimated that the diminution of the seas already had been going on for an additional two billion years.[156] The *Telliamed* incorporated the results of observation along the shores of the Mediterranean Sea where Maillet had traveled while a French diplomat in Egypt.[157] Maillet's observations and arguments about present-day geological processes represent an Aristotelian type of Theory, emphasizing questions taken up by Theorists from Palissy to Buffon to Lamarck about the gradual pace of aqueous deposition of strata, the geological effects of sea currents, the processes of shoreline erosion, and the degree of continuity between terrestrial and submarine landforms.[158] For example, Maillet argued that fossil shells were remnants of marine bodies, which could not have been either deposited

[155] For example, even the acceptance of mermaids was not as uncritical as it appeared to later readers, for Maillet assembled what he considered to be impartial and independent testimony (I owe this point to Rhoda Rappaport).

[156] Carozzi, *Telliamed*, 181 (the diminution of the seas upon the Earth for the past two billion years) and 182 (up to two billion years for the life of a large star).

[157] This fieldwork led Albert Carozzi to the startling conclusion, given Hutton's assessment of the *Telliamed* as a "physical romance" (page 325 above), that Maillet "used inductive methods like James Hutton" in contrast to other Theorists of the Earth; Carozzi, *Telliamed*, 3.

[158] Maillet's system is briefly described by Carozzi, *Telliamed*, 32–50, and Albert V. Carozzi, "De Maillet's Telliamed (1748): An Ultra Neptunian Theory of the Earth," in *Toward a History of Geology*, ed. Cecil J. Schneer, Proceedings of the New Hampshire Inter-Disciplinary Conference on the History of Geology, September 7–12, 1967 (Cambridge: MIT Press, 1969), 80–99. On Aristotelian Theories see "Aristotelian Theories of the Earth," beginning on page 188.

by a violent deluge nor transported through underground channels. If the *Telliamed* was not explicitly cited in later works because of its eternalistic and transformist implications, it lurked for decades as an unseen target of many researches which sought to correct its unfounded inferences and refute its mistaken implications.[159] As we have seen, Cuvier noted Lamarck's extension of positions advanced in the *Telliamed*.

Fifth, all consideration of the *Telliamed* aside, given the sheer abundance of Theories of the Earth it is hard to deny that in their own day they were in fact successful in establishing themselves. And they were durable: Theories of the Earth were published for two centuries, longer than the heyday of historical geology from the early nineteenth century until the mid-twentieth-century advent of plate tectonics.

Sixth, even the claim, absolutely critical to Porter's argument, that Theories of the Earth dropped dead without progeny at the turn of the nineteenth century is in itself a problematic premise.[160] Theories were not only popularized by writers such as Jules Verne or folk-science enthusiasts such as the scriptural geologists, but they were also associated with practical interests and economically significant investigations ranging from mining enterprises to Davy's metallic investigations. Moreover, geological works were often explicitly associated with Theories of the Earth; for example, the American reprint of Bakewell's geology contained Benjamin Silliman's supplemental essay on the "Consistency of Geology with Sacred History," which was a Theory of the Earth.[161] Lyellian principles of geology were hailed as a develop-

[159] The *Telliamed* "ranked among scientific books number six with seventy-two copies in a survey of the catalogues of 500 libraries of France in the eighteenth century. The proposed system was refuted and attacked actively for almost a century...." Carozzi, *Telliamed*, 4, reporting the survey carried out by Daniel Mornet, *Les Sciences de la Nature en France au XVIIIe Siècle* (Paris, 1911), 248. Cf. Daniel Mornet, "Les Enseignements des Bibliothèques Privées (1750–1780)," *Revue d'Histoire Littéraire de la France* 17 (1910): 449–496.

[160] This was suggested above by considering the example of Pallas; "On the Edge of Geology," beginning on page 263. Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101, lists over a dozen Theories published after 1800.

[161] On Verne and Davy see "Global Sections," beginning on page 372. Cf. Benjamin Silliman, "Consistency of Geology with Sacred History," in Robert Bakewill, *An Introduction to Geology: Intended to Convey a Practical Knowledge of the Science, and Comprising The Most Important Recent Discoveries; with Explanations of the Facts and Phenomena which serve to Confirm or Invalidate Various Geological Theories*, Second American from the Fourth London Edition (New Haven: Hezekiah Howe & Co., 1833), 389–479.

ment of the Huttonian Theory and de la Beche portrayed Lyell as a Theorist of the Earth in his well-known series of caricatures.[162] Although professionalization greatly altered the dynamics of publishing for textual traditions, possible continuities between Theories of the Earth and nineteenth-century meteorology, chemistry, geophysics and planetary physics remain largely unstudied, and many specialized investigations are needed before any claim of the abrupt demise of Theories of the Earth can be adequately substantiated.[163]

§ 6-iii. Appropriation Model: An Alternative to Marginality

Exploration of models for the development of scientific traditions other than a Marginality Thesis seems warranted. In Table 42 I have provisionally transposed to the Theories of the Earth tradition A. I. Sabra's well-known "appropriation" model for the establishment and sustaining of Islamic scientific traditions, formulated in opposition to older views of the marginality of Greek science in Islamic culture (Table 41).[164] This scheme is suggested with many qualifications, for the alleged marginality of science with respect to a culture differs from the alleged marginality of a textual tradition with respect to the emergence of a technical discipline. In particular, I have adapted Sabra's model to make it more applicable to textual traditions in general, and some reference will be made to it throughout the following chapters. However, the primary aim is not to establish a new model (too much work remains to be done

[162] See Figure 31 on page 274 and footnote 49 on page 285.

[163] For this purpose it is necessary to take into account investigations in meteorology, geophysics, cosmology and natural history as well as early geology; cf. Stephen G. Brush, Helmut E. Landsberg and Martin Collins, *The History of Geophysics and Meteorology: An Annotated Bibliography*, Garland Reference Library of the Humanities, no. 421; Bibliographies of the History of Science and Technology, no. 7 (New York: Garland Publishing, 1985); Stephen G. Brush, *Nebulous Earth: The Origin of the Solar System and the Core of the Earth from Laplace to Jeffries*, vol. 1 of *A History of Modern Planetary Physics*, 3 vols. (Cambridge: Cambridge University Press, 1996); James Rodger Fleming, *Historical Perspectives on Climate Change* (Oxford: Oxford University Press, 1998).

[164] A. I. Sabra, "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement," *History of Science* 25 (1987): 223–43. Sabra writes (p. 236): "In opposition to the marginality thesis I would suggest that what we see in the history of Islamic science is a process of assimilation ending in a complete naturalization of the imported sciences in Muslim soil."

for that) but to show that plausible alternatives to a marginality thesis exist, which substantiates the need to reassess the significance of the Theory of the Earth tradition.

TABLE 41. **Sabra's Appropriation Model for Scientific Traditions**

Stage	Islamic civilization
1. Translation	Active acquisition of ancient science through determined efforts of translation.
2. Assimilation	Marked by the emergence of an intellectual elite committed to the new science which nevertheless viewed themselves as faithful to the Muslim tradition, and consequently devoted themselves to reconciling the conflicts arising from the collision of the traditions.
3. Naturalization	Transfer of the new scientific thought and discourse into the existing culture, resulting in a thorough combination so that it became practiced by cultural leaders.
4. Transformation and Decline	Loss of the unity of the endeavor, as a consequence of its successful naturalization.

TABLE 42. **Appropriation Model for Theories of the Earth**

Stage	Time/Description	
1. Translation	Ongoing expert participation, enlistment and recruitment	
2. Textual Assimilation	17th century and the Burnet controversy	Appropriation, Consolidation, Self-constitution, Discourse formation (Chapter 5)
3. Technical Naturalization	18th century and early 19th century	Growth, Extension, Adaptive radiation (Chapter 6)
4. Transformation and Decline	Early to mid-nineteenth century	Speciation, Transformation, Displacement (Chapter 6)

Sabra's first stage refers to Islamic scholars' active acquisition of ancient science through determined efforts of translation. Transposed to Theories of the Earth, *Translation* refers to the processes by which experts in various technical discourses worked determinedly to translate their expertise into publicly-accessible form and to bring it to bear upon questions discussed in the Theory of the Earth tradition. By no means is this a passive or trivial accomplishment; continuing acts of translation are required to sustain a dynamic rather than kinematic textual tradition.[165] Translation includes the introduction and development of appropriate new techniques and investigative methodologies (e.g., mineralogy, fieldwork, study of fossils) within Theories of the Earth.

Second, Sabra's *Assimilation* stage describes the emergence of an intellectual elite in Islamic culture that was committed to the new science but nevertheless viewed themselves as faithful to the Muslim tradition. Transposed to Theories of the Earth, *Textual Assimilation* refers to the emergence in the seventeenth century of a textual tradition devoted to the discussion of natural order and historical contingency in the Earth's past. Seventeenth-century scholars and philosophers culled information about the Earth from a variety of sources including classical antiquities and history, meteorology, physics, cosmology, alchemy, theology, biblical exegesis, geography, and natural history, and these were translated into the new discourse of the Theory of the Earth. The initial constitution of a recognized textual tradition was completed in the controversies over the Theory of Thomas Burnet, although many earlier seventeenth-century texts (such as Descartes' *Principia*) were regarded as participating in an emerging tradition (if necessary, by retroactive attribution). Viewing themselves as faithful to philosophical and theological ideals, most participants devoted themselves to reconciling apparent conflicts between Theories of the Earth and other traditions by relying upon resources such as classical texts and other accepted sources of knowledge, emphasizing in particular the relationship between Theories of the Earth and biblical traditions of exegesis for the creation week (*hexameron*) or deluge. Assimilation is evidenced by an emphasis on the harmony of texts, sacred, classical, and empirical (the "book of God's Works"). The assimilation stage of Theories of the Earth is therefore apparent in Whiston's *New Theory of the Earth*, Barin's *Le Monde Naissant* or (much later, in another wave) William Buckland's *Reliquiae Diluvianae* and Edward Hitchcock's *The Religion of Geology.* Attendant harmonizations and reconciliations were not merely retrograde distortions and vulgar popularizations, but a mani-

[165] "Books don't read themselves.… the reader must be trained. That a group of scientists is capable of agreeing on what a book says should also be taken as an achievement, a balancing of forces, not as the course of nature." Peter Barker, "Scientific Revolutions," 16. X-Ref to boundary objects in Ch. 1.

festation of successful assimilation. The seventeenth-century Textual Assimilation of Theories of the Earth is explored in Chapter 5.

Third, Sabra's *Naturalization* stage refers to the transfer of the new scientific discourse beyond the elite circle of Islamic natural philosophers themselves into the wider culture so that it became practiced and endorsed by cultural leaders. Transposed to Theories of the Earth, *Technical Naturalization* refers to the transfer of the new discourse beyond the textual tradition itself into other cultural spaces, so that it became practiced by leaders of other cultural and technical traditions. This outward movement whereby questions, theories, and methods become pursued in a more specialized manner outside the discourse has already been described as the transmogrification of a textual tradition into one or more technical disciplines. The eighteenth-century Technical Naturalization of Theories of the Earth is explored in Chapter 6.

Fourth, Sabra's last stage of *Transformation and Decline* results not from any inherent defect in the tradition, but due to a loss of unity of the endeavor as a consequence of its successful naturalization. In other words, differentiation of traditions occurs so long as naturalization continues vigorously; displacement occurs when translation slackens. Transposed to Theories of the Earth, the transformation of the Theory of the Earth tradition resulted as a consequence of its naturalization from the shaping of practices in diverse professional fields (including mathematical cosmology, geognosy, palaeontology, historical geology, geophysics, meteorology, geography, and natural history). Complete transformation in this specific sense refers to the later stages in the differentiation of technical disciplines, coupled with a decline in the translation of new technical perspectives into the textual tradition. Because translation was no longer needed, perhaps because of increasing professionalization, Theories of the Earth declined by the mid-nineteenth century, and in some ways were slowly displaced by folk-science vestiges (Table 43).

TABLE 43. **Transformation of a Textual Tradition (Appropriation Model)**

1. Assimilation
Translation successful, predominates, a textual tradition is established

2. Sustained Tradition
Translation and Naturalization equally successful

3. Decline
Naturalization successful, predominates; a textual tradition lapses into folk science with a relative lack of translation (expert input)

§ 6-iv. Marginality, Incommensurable Mentalities, and Genres of Thought

Understanding of the transformation of natural knowledge in textual traditions has been obscured by several historiographical and philosophical red herrings. On the most fundamental level, widespread acceptance of a marginality thesis for Theories of the Earth reflects an all-too-common tendency among historians of science to focus critical attention on "turning points" and moments of dramatic change. Theories of the Earth have been consigned to a Procrustean bed all-too-snugly tucked between the two turning points of the "Scientific Revolution" and the origin of historical geology. By exclusively focusing upon turning points, historians tend to downplay significant questions about the intervening propagation and transformation of traditions, obscuring the dynamics of less abrupt changes that happen not to square nicely with our expectations of homogenous research programs successively replaced through revolutionary paradigm shifts. Revolutionary breaks with tradition attract more explanatory attention than the dialectical transformation of a tradition, and our historiographical neglect of the latter not only obscures its potential significance but also habituates the historian to expect revolutionary breaks where other models of change are needed. To adequately characterize the translation, assimilation, and naturalization of Theories of the Earth in the seventeenth and eighteenth centuries, we must go beyond the dichotomy of "continuity vs. revolution" and examine the transformation of dynamic textual traditions.[166]

In pursuit of his dubious but well-intentioned strategy of radically dissociating Cuvier from the tradition, Martin Rudwick described Theories of the Earth as a monolithic and homogeneous tradition, the character of which was determined once for all by its Cartesian

[166] This paragraph is indebted to Peter Barker, "Understanding Change and Continuity," in *Tradition, Transmission, Transformation*, ed. F. Jamil Ragep and Sally P. Ragep (Leiden: Brill, 1996), 527–550. Barker argues that apparent stasis as well as change requires explanation: "Stability is a special case of change." Transmission, Barker suggests (p. 17), "is not the norm, but rather a special case of appropriation."

origin. A reified Theory of the Earth tradition therefore had to be set aside, he argues, before a sense of contingent geohistory could arise:

> It proposed models or 'systems' for the causal development of the whole earth, but they were deeply ahistorical. True to their Cartesian origins, they were genetic, or—better still—*epigenetic* in character. Each 'system' posited a set of initial conditions, combined it with a set of physical principles, and then derived a sequence of stages through which the earth must have passed, and through which it would have to pass in the future. That sequence of stages took place within time, of course, but it represented a programmed unfolding of physical states;.... all of them shared this general character.... What all these 'systems' lacked was any significant element of the *contingency* that would have marked a truly geohistorical narrative, any sense of the unpredictable complexity and particularity of history.[167]

Despite the fact that Theorists themselves argued over whether contingency played a significant role in Earth history (as in Hutton's critique of Buffon's Theory as "founded on a mere accident," and of Deluc's as a "history of a disaster"[168]), something like Rudwick's characterization would be necessary to sustain the view that the rise of historical geology was a revolutionary transition from one essentially unchanging object to another.[169]

Yet Theories of the Earth did not comprise a single unchanging entity that was replaced by a monolithic and radically different geology. Rather, through the seventeenth and eighteenth centuries the Theory of the Earth tradition was dialectically redefined by the continual introduction of new techniques, perspectives, and methodological or epistemic keys.[170] In a

[167] Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 27.

[168] See page 326.

[169] My analysis and phrasing follows that of Peter Barker in a different context: "The fundamental problem ... was that of explaining the change in the content of science before and after a scientific revolution. But the problem was framed as the transition from one essentially unchanging object to another." Peter Barker, "Scientific Revolutions," 15.

[170] The introduction of these new perspectives counts as the Translation component of the Appropriation model outlined in Table 42. "Tradition" in the sense used here by no means implies a linear and cumulative development within a rigidly-defined conceptual framework, but a historical lineage with remarkable cross-breeding ability. The phylogeny of Theories of the Earth more closely resembles that of dogs than ammonites, although a few "living fossils" persisted long after their closer kin ceased to flourish. Individual texts may display a nominal unity but nevertheless betray historical continuity.

different context, Rudwick recognized the significance of the growth of an evolving discipline, and warned of the danger of "second-order Whiggism" that results from neglecting it:

> Many detailed historical studies—some of them otherwise admirable—analyze the earlier phases of specific scientific developments with repeated forward reference to problems that had not yet arisen, experiments not yet performed, theories not yet devised, and publications not yet composed. Even historians of science who are zealous in sniffing out the 'presentist' or 'whiggish' heresies of others are themselves often guilty of what may be termed the 'second-order whiggism' of retrospective description. This may not be as blatant as the presentist interpretations of some scientists, with their repeated invocation of what 'we now know' as an unproblematic standard for understanding the past history of their field. The forward reference may not be to present knowledge, but rather to the later and mature work of the same individual or to the later development of the same discipline—however unmodern that may still have been. But even this precludes any genuine understanding of the *processes* by which new knowledge is shaped.[171]

Second-order Whiggism occurs when a historian discounts the ongoing transformation of traditions. It is second-order Whiggism to characterize the Theory of the Earth tradition by singling out Descartes as a paragon representative and then to contrast the tradition by means of forward references to the emergence of early geology. It would be as problematic to characterize geology today only by reference to geology before plate tectonics, as to characterize later Theorists among Cuvier's contemporaries solely by reference to early ones such as Descartes. Because of the extended radiation of a dynamically-changing tradition, there is a greater difference between later and earlier Theorists than between later Theorists and early geologists.

If Theories of the Earth were speculative whereas early geology was based on observation; if Theories of the Earth were controversial and individualistic whereas early geology proceeded by collective and consensual endeavor; if Theories of the Earth were ahistorical whereas early geology was deeply historical, then indeed one could argue that Theories of the Earth were a pre-geological *mentality* that was displaced by an endeavor of a completely different kind. Theories of the Earth are often referred to as a *genre* to convey roughly this meaning, implying

[171] Martin J. S. Rudwick, *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), 11-12.

that they were a mentality at best irrelevant to, and perhaps even an obstacle for, the development of early geology and above all, suggesting that they were incompatible and incommensurate with more developed thinking about the Earth. Jacques Roger began the practice of referring to Theories of the Earth as a distinct *genre* and, although he argued that Theories of the Earth had their own intellectual coherence and validity, he emphasized the incommensurability of different genres of thought. This is evident in Roger's account of the origin of Theories of the Earth as well as of their demise; for Roger, Descartes invented the tradition almost *de novo*, and it was literally impossible for a pre-Copernican to have developed a theory of the Earth.[172]

To interpret the significance of Greek thought on the development of western culture, in the early twentieth century the sociologist Lucien Lévy-Bruhl developed the idea of a pre-logical or primitive *mentalité*. To my knowledge, Roger did not adapt his analysis to conform to Lévy-Bruhl. Rather, Roger's historiography of science drew more upon Gaston Bachelard's program for the history of science as the charting of changes in the conception of reason, understood as developing over time with occasional sharp epistemic breaks or ruptures.[173] There are a number of historiographical parallels between the characterization of Theories of the Earth as a distinctly pre-geological *genre* and Lévy-Bruhl's characterization of pre-Greek thought as a pre-scientific *mentality*, regardless of the question whether Roger directly or indirectly appropriated any of his categories from Lévy-Bruhl. Because of these similarities, the validity of mentalities as an explanation for the development of pre-Socratic thought has been challenged by G. E. R. Lloyd on a number of grounds which provide a helpful model for three analogous criticisms of the description of Theories of the Earth as a genre of thought.[174]

[172]For Roger's account of the origin of Theories of the Earth see "Roger's Demarcationist Criteria: Global Directionalism," beginning on page 211, and "Case 1: The Meteorological Tradition," beginning on page 222. On Theories of the Earth and *literary* genres, not to be confused with *genres of thought* or *mentalité* as discussed here, see "Hamilton and Literary Genres of Theories of the Earth," beginning on page 159.

[173]For a succinct analysis of Bachelard's views see Gary Gutting, *Michel Foucault's Archaeology of Scientific Reason*, Modern European Philosophy, ed. Raymond Geuss (Cambridge: Cambridge University Press, 1989), chapter 1.

First there is the "evident extravagance in allowing a single individual . . . several mentalities."[175] Challinor's dilemma regarding the positive geology of John Whitehurst, Carozzi's description of Maillet as a follower of "inductive" methods like Hutton, the appropriation of Hutton as the father of geology, or the difficulties of demarcation encountered with Cuvier suggest that one could multiply examples of dual-mentality thinking, of persons who reasoned simultaneously in two supposedly incompatible genres of thought.[176]

Second, a sensitivity to actors' categories opens up alien aspects of original contexts of discourse in ways that remove the need to postulate the operation of divergent mentalities.[177] For example, no appeal to "mentality" is needed to explain Theorists' attention to kinds of evidence no longer prominently deployed in geological publications. Theorists from Burnet to Cuvier, along with their readers, often took textual evidence and practices of textual communication very seriously, but this disposition *per se* does not make their conclusions speculative or even necessarily non-empirical. Instead of a dichotomy between the *speculation* in which Theorists of the Earth indulged and the *careful observation* practiced by early geologists, attention to Theorists' categories will enable historians to understand that Theorists were seeking evidence from a variety of sources, eventually including but not limited to stratigraphical fieldwork. Instead of resting in the characterization of Theories of the Earth as a speculative endeavor, historians will reassess them as a dynamic textual tradition rather than a failed tech-

[174]Geoffrey Ernest Richard Lloyd, *Demystifying Mentalities, Themes in the Social Sciences* (Cambridge: Cambridge University Press, 1990); hereafter Lloyd, *Demystifying Mentalities*.

[175]Lloyd, *Demystifying Mentalities*, 5.

[176]On Challinor and Whitehurst see page 284; on Carozzi and Maillet see footnote 157 on page 339; on Hutton as the father of geology see page 275; on Cuvier and the rhetoric of demarcation see page 316.

[177]Lloyd comments, regarding the distinctions between science, myth, magic, and the literal vs. the metaphorical: "The all-important distinction that has scrupulously to be observed is—to put it in the social anthropologists' terms—that between *actors*' and *observers*' categories. In the evaluation of the apparently puzzling or downright paradoxical, a crucial issue is, I argue, precisely the availability or otherwise of explicit concepts of linguistic and other categories.... This is particularly true when the distinctions *we* commonly deploy force issues that are alien to the original actors' contexts of discourse: once *those* contexts of discourse are reinstated, much of the temptation to postulate divergent mentalities in this connection lapses." Lloyd, *Demystifying Mentalities*, 7. Lloyd continues (p. 10): "due attention must be paid to the general rules, implicit or explicit, for the conduct of discussion, to the expectations entertained by the participants concerning the criteria for an adequate performance, and especially to the extent to which, and to ways in which, a point of view is open to challenge."

nical discipline, and investigate what kinds of evidence specific Theorists invoked in particular contexts, and to what degree they contributed to the development and appropriation of new kinds of evidence. Moreover, the establishment of the speculation vs. observation dichotomy will come to be seen as one part of the displacement of the textual practices of Theories of the Earth by the technical practices of early geology, a rhetorical and social achievement in disciplinary boundary-drawing rather than a self-evident cause of that displacement. That is, the rhetorical habit of demarcating early geology from later Theories of the Earth on the basis of observation vs. speculation will be seen as "not just an innocent, neutral piece of logical analysis, but a weapon forged to defend a territory, repel boarders, put down rivals."[178]

It was noted earlier that in 1816 the English geologist William Phillips published *An Outline of Mineralogy and Geology* which announced that its "freedom from theory" made it uniquely attractive for public notice.[179] Baconian rhetoric pervades the work: "Disclaiming all theory,"[180] Phillips pledged that his outline would not "in any degree be dependent upon, or connected with, the many crude and almost barbarous theories of others, who long amused and even dazzled the world by the splendour of their inventions; which tended to retard, rather than to forward an inquiry into the nature of the globe we inhabit."[181] To the contrary, Phillips' readers could be assured that:

> I demand no assent to theory, for I will not broach a theory. I offer alone the results of inquiries among the facts and phenomena of nature, by men whose love

[178]Lloyd, *Demystifying Mentalities*, 23. Lloyd was referring, of course, not to the speculative vs. observational character of Theories of the Earth *vis a vis* historical geology, but to the Greek development of the distinctions between the literal vs. the metaphorical and the mythical vs. the rational. See "Textual versus Technical Traditions," beginning on page 79.

[179]William Phillips, *An Outline of Mineralogy and Geology, Intended for the use of those Who may desire to become acquainted with the Elements of Those Sciences; Especially of Young Persons* (New York: Printed and Sold by Collins and Co., 1816), iii; hereafter Phillips, *Outline of Mineralogy and Geology.*

[180]Phillips, *Outline of Mineralogy and Geology*, 67.

[181]Phillips, *Outline of Mineralogy and Geology*, 1. Phillips later repeated the now-familiar themes, commenting (p. 92): "how incapable and absurd are the speculations of mere closet-philosophers; who, relying on their inventive powers, and on the extreme difficulty of contradicting their silly theories, indulged themselves in speculations scarcely more ridiculous than it would be to assert that the globe is an egg or an oyster."

> of nature and of truth, has rendered their researches invaluable to science: researches amid regions always open to the doubting or disbelieving.[182]

However free from "theory," what Phillips offered was not exactly free from "Theories," given that two of the men he admired for their "love of nature and of truth" were Werner and Cuvier, widely regarded as two of the major Theorists of the Earth.[183] Phillips followed Cuvier in reconstructing catastrophic revolutions of the Earth caused by repeated incursions of the sea. In no uncertain terms Phillips explained:

> It is beyond a doubt, that there have been many catastrophes of the same nature, though not perhaps to the same extent. What has been the agent employed in the production of these catastrophes is most obvious. It is not to be doubted that there have been successive irruptions and retreats of the sea; and it seems equally certain that the final result has been the universal depression of its level.[184]

Similarly, Phillips followed Werner in adopting a Neptunist interpretation of the origin of the strata: "The numerous facts already adduced, have led us decidedly to adopt the belief that the sea must have stood at an elevation greatly above the general level of the earth."[185]

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[182]Phillips, *Outline of Mineralogy and Geology*, 94.

[183]Attempting to build his credibility as the purveyor of unbiased conclusions, Phillips continued: "Amongst these men, let us remember that we have an Humboldt, a Werner, a Saussure, and a Cuvier. What but the love of truth and of science could have induced Humboldt to traverse whole continents, or to ascend the Andes more than 18,000 feet above the level of the sea; or Werner, the great German geologist, to bestow his life in examining the rude and mountainous regions which surrounded him, and in teaching the results of his inquiries? What but love of truth and of science could have led Saussure to investigate every corner of the Alps, during twenty years; or have induced Cuvier to bestow twenty-five years of his life in the study of comparative anatomy and osteology, with a view principally, if not solely, to the illustration of the nature of our globe?" Phillips, *Outline of Mineralogy and Geology*, 94. We have already discussed the relation of Werner ("Geognosy and the Wernerian Adaptive Radiation," beginning on page 116), Humboldt (page 119), and Cuvier (page 313 ff) to Theories of the Earth, and Saussure is included in Table 9, "Works with titles containing the phrase Theory of the Earth," on page 101. Saussure related his work to the Theory of the Earth tradition by publishing heuristic queries as an outline of investigations for the Theory of the Earth in the final volume of his *Voyages dans les Alpes*; Horace Bénedict De Saussure, "Agenda, Ou Tableau général des Observations et des Recherches dont les résultats doivent servir de base à la Théorie de la Terre," *Journal des mines* 4 (1796): 1–70, and Horace-Bénedict De Saussure, "Agenda, ou Tableau Général des Observations & des Recherches dont les résultats doivent servir de base à la théorie de la terre," in *Voyages dans les Alpes, Précédés d'un Essai sur l'Histoire Naturelle des Environs de Geneve*, 4 vols. (Neuchatel: Chez Louis Fauche-Borel, 1796), 4: 467–529. For the distinction between "theory" and "Theory" see page 44.

[184]Phillips, *Outline of Mineralogy and Geology*, 73-74. Phillips also followed Cuvier in his rehearsal of previous Theories of the Earth, identifying many of the same Theorists with largely similar rhetorical descriptions; see Phillips, 62-65.

[185]Phillips, *Outline of Mineralogy and Geology*, 159. Phillips defended at length Werner's reputation as a careful geological observer despite conceding that he was a Theorist of the Earth. His reliance upon Werner's classification of rocks was pronounced, and he included a Wernerian section of a mountain. See Phillips, 113-118. For an excerpt, see the quote above on page 56.

Despite manifest continuities between his geology and Theories of the Earth, Phillips could counsel his readers to a serene trust in his exposition:

> Geologists have truth for their object. That faculty of genius which consists in invention no longer presides; the theories which attributed the origin of the globe to a portion of the sun struck off by a comet, and fifty others equally absurd, which by their splendour once dazzled mankind, are gone by and neglected. Patient and profound investigation has taken their place; producing research nearly to the summits of our most elevated mountains, and to the greatest depths to which the miner can descend.[186]

His use of Cuvier and Werner makes clear that Phillips' rhetorical demarcation between his geology and the Theory of the Earth tradition on the basis of "observation vs. speculation" raises interesting questions about the justification of his own geology before his particular audience, but need not be regarded as an accurate non-retrospective characterization of Theories of the Earth as a textual tradition. This is to repeat what was said under the heading "Theories and Facts," beginning on page 52, that the observation vs. speculation polarity should not be adopted as an observers' category, for historical interpretation, in a way that naively mimics the actors' category.

A third point of Lloyd's historiographical critique of *mentality* is that the deployment of actors' categories regarding temporal sensibilities, not modern definitions and analytical distinctions, should frame the analysis of natural order and historical contingency. Just as Cambrian life-forms differ from modern ones, so the contingent history of the Earth envisioned by Theorists such as Burnet, Buffon or Deluc will not be what a modern historian expects to find based on retrospective themes such as the age of the Earth or nineteenth-century stratigraphy. The modern historian might easily miss the significance of the establishment of new terms of debate, of the construction of the categories through which the historical actors introduced the role of contingency in their own particular contexts, from which it may later have been

[186] Phillips, *Outline of Mineralogy and Geology*, 188.

applied or transfered (perhaps piecemeal) to discussions more familiar to modern historians. Lloyd comments:

> the statement of the principles itself was of the greatest importance, since once they were made explicit they could be, and they were, used as a standard by which to judge performance—including, indeed, in some instances, the inadequate performance of the very writers who were responsible for stating the principles.[187]

Instead of a dichotomy between historical geology and ahistorical Theories of the Earth we need a detailed and nuanced reassessment of the different contexts and discourses in which contingency and historical thinking were debated by Theorists of the Earth, and an exploration of the degree to which the legitimacy of historical explanations was established *in those contexts*. In addition to classical scholarship, antiquarianism, cosmology and other traditions, hexameral idiom provides just such a context, made more promising because of humanist interpretations of the days as successive unique events.

§ 6-v. Definitions of Historical Sensibility redivivus: Robert Hooke

David Oldroyd is one of the most versatile and accomplished historians of geology broadly considered, whose published research has dealt with the development of geological ideas in the last four centuries as well as philosophical and historiographical issues arising from these studies.[188] In an early article, still cited with approval in Oldroyd's recent survey, Oldroyd identifies the rise of German historicism at the end of the eighteenth century as the key catalyst for the development of historical as opposed to genetic sensibilities of the Earth.[189] Oldroyd's contention that German Historicism contributed much to subsequent historical sensibilities is most valuable and illuminating, yet this important article is welcome on another count because it expresses with great forcefulness and clarity several widely-

[187]Lloyd, *Demystifying Mentalities*, 33.

adopted historiographical categories, and therefore offers an opportunity to consider how discussions framed in such terms may disregard the changing deployment of actors' categories.

Earlier Theorists from Steno to Werner, Oldroyd asserts, universally held to genetic views without any significant degree of contingent history.[190] Our aim in this section is not to support or refute Oldroyd's specific contentions so much as to clarify some of the categories and assumptions involved. To do so we may examine the case of Robert Hooke, on whose writings Oldroyd has frequently published. Again, our purpose is not to show that Hooke's Theory was historical instead of cyclic or genetic, but to consider how an argument that Robert Hooke's Theory was not historical is framed:

> Hooke, in 1688, spoke to the Royal Society about the possibility of using fossils 'to raise a Chronology out of them, and to state the intervalls of Times wherein such, or such Catastrophies and Mutations have happened.' But Hooke did not, in fact, actually write a history of the globe on the basis of fossils or observations of strata, and neither did any of his contemporaries. Moreover, his interest in this discourse to the Royal Society was a means towards providing secure empirical support for the traditions of catastrophes indicated by ancient mythologies—for *man's* history in other words—rather than as a means whereby the geological his-

[188] The following are a representative sampling of Oldroyd's many publications: On ancient vulcanism, P. B. Paisley and David R. Oldroyd, "Science in the Silver Age: Aetna, a Classical Theory of Volcanic Activity," *Centaurus* 23 (1979): 1–20. On the seventeenth century, David R. Oldroyd, "An Examination of G. E. Stahl's *Philosophical Principles of Universal Chemistry*," Annals of Science 20 (1973): 36–53; David R. Oldroyd, "Some Neoplatonic and Stoic Influences on Mineralogy in the Sixteenth and Seventeenth Centuries," *Ambix* 21 (1974): 128–156; and David R. Oldroyd, "Mechanical Mineralogy," *Ambix* 21 (1974): 157–178. For the eighteenth century, David R. Oldroyd, "Some Phlogistic Mineralogical Schemes, Illustrative of the Evolution of the Concept of 'earth' in the Seventeenth and Eighteenth Centuries," *Annals of Science* 31 (1974): 269–305; and David R. Oldroyd, "Mineralogy and the 'Chemical Revolution'," *Centaurus* 1 (1975): 54–71. For the nineteenth century, including a methodological defense for the historiographical utility of reconstructing field-work; David R. Oldroyd, *The Highlands Controversy: Constructing Geological Knowledge through Fieldwork in Nineteenth-Century Britain* (Chicago: University of Chicago Press, 1990). On Hooke's pronouncements on scientific methodology, David R. Oldroyd, "Robert Hooke's Methodology of Science as Exemplified in his 'Discourse of Earthquakes'," *British Journal for the History of Science* 6 (1972): 109–130; and David R. Oldroyd, "Some Writings of Robert Hooke on Procedures for the Prosecution of Scientific Inquiry, Including his 'Lectures of Things Requisite to a Ntral [*sic*] History,'" *Notes and Records of the Royal Society of London* 41 (1987): 145–167.

[189] David R. Oldroyd, "Historicism and the Rise of Historical Geology," *History of Science* 17 (1979): 191–213, 227–257, hereafter Oldroyd, "Historicism"; Oldroyd's usage of "historicism" and "genetic" sensibilities is discussed above in "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22. Recent approval of this study is found in David R. Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (Cambridge: Harvard University Press, 1996), 328, note 17. Cf. W. R. Albury and David R. Oldroyd, "From Renaissance Mineral Studies to Historical Geology, in the Light of Michel Foucault's *The Order of Things*," *British Journal for the History of Science* 10 (1977): 187–215.

[190] For a contrary interpretation of Steno see footnote 19 on page 15 above, and "Steno's Tuscan Autopsy," beginning on page 562. Oldroyd's treatment of Werner is discussed in Chapter 6.

> tory of the *Earth* might be elucidated. And in his earlier statement of geological doctrine (1668) we have a cyclic theory which Hooke did not seek to justify by examination of the details of individual strata, though he thought that the presence of fossils within the strata could be accounted for by means of his theory.... His geological work meshed with the concern with man's past that was evinced in his day. But this concern was with ancient mythology, Biblical records, and millenarian doctrines—confirming the unfolding of history according to some inspired plan—rather than with the understanding of man's past through the painstaking piecing together of the secular record of man's affairs.[191]

This remarkable paragraph intertwines a number of objections, two threads of which we may unravel to analyze separately below. In sum, Oldroyd argues for Hooke's lack of geohistorical sensibility because Hooke's understanding of human history was based upon neither strata nor secular records, but upon mythology and some kind of inspired plan.[192]

Records of Man vs. Records of the Earth

Oldroyd objects that a historical sensibility is incompatible with Hooke's interest in human history rather than in prehuman geohistory. However, this erects a false dichotomy for the seventeenth and early eighteenth centuries. If Hooke's geological investigations were a "means towards providing secure empirical support for the traditions of catastrophes indicated by ancient mythologies—for *man's* history in other words," this does not rule out that the motivation also moved in the other direction, *i.e.*, that Hooke's investigations into mythology and classical history were equally a means of providing secure empirical support for his views on earthquakes, fossils, and changes in the Earth's crust. The studies of of Schneer, Drake, Turner, and Rappaport conclude that the latter was indeed the case.[193] Hooke's historical documentation that earthquakes occur around the globe bolstered his case that they were a regular feature of the Earth and not merely accidental phenomena. The often-voiced requirement that Theorists provide evidence from classical history was a sign of the acknowledged

[191] Oldroyd, "Historicism," 195–196.

[192] Oldroyd interprets the work of Steno as likewise unhistorical for similar reasons as Hooke's; see below on page 575.

limitations of reasoning only from causes (*propter quid*).[194] And textual investigations regarding the subject matter of mythology were often regarded as legitimate historical exercises according to contemporary standards. Hooke's own attempts to reconstruct factual records of actual events obscured by legendary accretions or hidden in a tradition of *prisca sapientia* were no less grounded than similar investigations by Isaac Newton and Thomas Burnet, among others.[195]

More generally, an unspoken premise seems to underlie objections of this sort; namely, that a developed sense of the divergence of human history and geological time is an essential prerequisite for holding to a view of Earth history as contingent rather than genetic. This premise is false. On this point attention to actors' categories would require, at a minimum, consideration of how in the late seventeenth century one might have gone about believing in an Earth indefinitely older than humanity. Such a belief was not impossible. To depart from Hooke for a moment, one example among the many supposedly-literal interpretations of the

[193]For Schneer and Drake see the discussion accompanying Table 1, "Origins of Historical Sensibilities in the Earth Sciences," on page 17. Chapman makes a similar argument with respect to Halley's use of historical evidence to critique Hooke; Allan Chapman, "Edmond Halley's Use of Historical Evidence in the Advancement of Science," *Notes and Records of the Royal Society of London* 48 (1994): 167–191. Turner characterizes the philosophers at Oxford who rejected Hooke's theory of polar wandering as maintaining a position of "balanced skepticism" with a "firmer control of the historical evidence for latitude and meridian observations than Hooke." The burden of proof lay upon Hooke to show how his Theory could be, as John Wallis put it, "without overthrowing the credit of all History, sacred and profane." A. J. Turner, "Hooke's Theory of the Earth's Axial Displacement: Some Contemporary Opinions," *British Journal for the History of Science* 7 (1974): 167. An indispensable analysis of Hooke's contemporary audience is Rhoda Rappaport, "Hooke on Earthquakes: Lectures, Strategy and Audience," *British Journal for the History of Science* 19 (1986): 129–146. Rappaport points to one interesting example of Hooke's use of mythology to provide empirical support for his geological views: Hooke sought to substantiate the Atlantis myth of Plato by discussing the travel reports of Hanno the Carthaginian, interpreted by Hooke as an eye-witness account of the aftermath of a great Atlantis earthquake; cf. Rappaport, 138. Rappaport concludes (p. 141): "A defence of the theory of earthquakes had, indeed, been Hooke's grand strategy throughout his lectures, and his forays into astronomy and Euhemerism [interpretation of pagan texts] may be viewed at least in part as tactical manoeuvres designed to provide his audience with additional persuasive evidence. From Hooke's point of view, a mechanism to account for the burial of fossils was absolutely essential if his hearers were to adopt his view of the nature of fossils themselves." Oldroyd has conceded this point: "Hooke made use of ancient texts in order to develop, and attempt to defend, his ingenious theory of the Earth.... To our knowledge, this use of ancient sources as a means of attempting to verify empirically a modern scientific hypothesis was the first significant example of its kind.... Thus, for the first time, the ideas of the Ancients were mustered not just as sources of scientific theory, but for the empirical information they might furnish to help verify a theory." Kirsten Birkett and David R. Oldroyd, "Robert Hooke, Physico-Mythology, Knowledge of the World of the Ancients and Knowledge of the Ancient World," in *The Uses of Antiquity: The Scientific Revolution and the Classical Tradition*, ed. Stephen Gaukroger, Australasian Studies in History and Philosophy of Science, ed. R. W. Home, no. 10 (Dordrecht: Kluwer Academic Publishers, 1991), 145. That Hooke was by no means the first will be apparent in the discussion of Burnet and others in Chapter 5.

hexameron was that of William Ames, the renowned Puritan theologian who was one of the chief influences upon the drafting of the Westminster Confession. Ames, who was also an alchemist, suggested that the six days were noncontiguous 24-hour days of creation separated by indefinite periods of time during which nature ran her course.[196] More commonly, however, one might hear of the long intellectual tradition, going back to Aristotle and Philo, of the eternity of the world; *i.e.*, of the infinite temporal existence of both the Earth *and humans*. Arguably hexameral views such as William Ames' have more of historical contingency in them than does the doctrine of the eternity of the world, yet if we restrict our observers' category of

[194]Hooke argued that earthquakes may be inferred to have occurred not only from historical records or eye-witness reports, but also—reading the Book of Nature equally alongside the books of the ancients—from the "Signs and Monuments" of fossils and dislocated strata: "Earthquakes... have in all Ages been in the Earth, tho' we have no Histories or Records that have preserved the Memory of them, but only such Signs and Monuments as they have left by the unequal ragged and torn Face of the Surface of the Land and the Bodies that are discovered [e.g., ammonites]; which proves that they had some time an other Position than they are found to have at the present." The last clause refers to Hooke's explanation for the cause of earthquakes, i.e., that sinking and elevation (including from earthquakes) result from a shifting of the Earth's center of gravity and a changing position of the axis of rotation within the Earth (polar wandering). Polar wandering explains Hooke's discovery on the Isle of Wight of fossils of life-forms such as the ammonites which he supposed must have inhabited a tropical climate and have become extinct. Rather than being transported by a deluge or via subterranean circulations, Hooke argued that such fossils are now discovered in the places where they actually lived and were suddenly buried by earthquakes. Thus Hooke combined deductive reasoning from causes with empirical evidence of natural effects so that his Theory might be "determin'd both *a Priori* by Theory, and also *a Posteriori* by Experiments or Observations." Robert Hooke, *The Posthumous Works of Robert Hooke . . . Containing his Cutlerian Lectures, and other Discourses, Read at the Meetings of the Illustrious Royal Society* (London: Publish'd by Richard Waller; Printed by Sam. Smith and Benj. Walford, 1705), 347, hereafter Hooke, *Posthumous Works*; reprinted according to Rappaport's chronology in Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford: Oxford University Press, 1996), 246–247, hereafter Drake, *Restless Genius*.

[195]The problem of the wisdom of the ancients is discussed in Chapter 2 primarily with respect to Burnet. Yushi Ito argues that Hooke's interest in classical sources followed his reading of the 1684 English translation of Burnet's Theory, which Hooke regarded as directionalist: "Hooke... showing an interest in Burnet's theory, undertook a historically oriented study of the Earth and began to cite passages from Hanno's *Periplus*, Plato's *Timaeus*, Ovid's *Metamorphoses* and Aristotle's *Meteorologica* to prove that cyclic alterations had occurred in the Earth's surface.... Just as Burnet had consulted the works of the ancients in an attempt to find a description of the antediluvian Earth, Hooke now followed suit in search of evidence that there had been cyclic changes in the past." Ito continues that (p. 304): "Hooke's lectures of 1688 show clearly that he built up his theory of the Earth's history under the stimulus of Burnet's works." Yushi Ito, "Hooke's Cyclic Theory of the Earth in the Context of Seventeenth Century England," *British Journal for the History of Science* 21 (1988): 302. Cf. the different view of Rhoda Rappaport, "Hooke on Earthquakes: Lectures, Strategy and Audience," *British Journal for the History of Science* 19 (1986): 138, note 42. Ito's characterization of Hooke's Theory as cyclic in contrast to Burnet's directionalism relies primarily upon Hooke's rejection of Burnet's account of the deluge and the ocean-less antediluvian globe. But the latter were often rejected by those who preferred a different but still directionalist perspective (such as Robert St. Clair, questionably cited by Ito as adhering to a modified cyclic Theory of the Earth). Hooke's theory was cyclic in many respects, but he also conceded a lessening of the intensity of earthquakes over time, so further reassessment is warranted along the lines of David R. Oldroyd, "Geological Controversy in the Seventeenth Century: 'Hooke vs. Wallis' and its Aftermath," in *Robert Hooke: New Studies*, ed. Michael Hunter and Simon Schaffer (Woodbridge, Suffolk: Boydell Press; Rochester, NY: University of Rochester, 1989), 207–234; cf. footnote 206. On St. Clair see below, "St. Clair Confutes the Abyssinian Philosophy, 1697," beginning on page 504.

"prehuman history" to merely those who argued for vast eons of passed time we will miss the significance of the establishment of new terms of debate, of the construction of the categories through which the historical actors introduced the role of contingency in their own particular contexts. Ultimately, it may be noted that an objection of this sort actually sidesteps Oldroyd's main issues, for it moves the discussion away from the question of "historical vs. genetic," Oldroyd's original terms of analysis,[197] to a consideration privileging the Earth's duration. The age of the Earth from Moses to Darwin constitutes a frame of reference more familiar to modern historians, but it makes no sense when sorting out genetic and historical views to disregard the actors' hexameral context when they argued against a steady-state planet whatever its age. As early as 1668 Hooke referred to "that extraordinary Earthquake" by which God separated the dry land from the universal ocean on the third day, a singular change in what had been to that point an onion-skin globe of exact spherical form.[198] Hooke explicated the first chapter of Genesis at greater length two decades later, where the greatest earthquake in Earth history occurred on the third day and played the same role of initiating the surface irregularities of the globe. Much like contemporaries such as William Whiston and Théodor Barin (whose Theories are examined in Chapter 5), Hooke appropriated Burnet's egg-shell model of the formation of the Earth into a hexameral and antediluvian context. For the second day Hooked interpreted the firmament as referring to an outer foundation layer of the Earth, and the separation of the waters above from the waters below he interpreted as referring to liquid layers on either side—the waters above representing a universal primeval ocean. This uniform watery surface lasted only until the third day (not until the Deluge, as Burnet would have it), as Hooke explained:

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[196]Of course, in a literal sense five of the hexameral days were prehuman periods. On Ames' alchemy see William R. Newman, *Gehennical fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge: Harvard University Press, 1994), 37. On his hexameral exegesis see C. John Collins, "How Old is the Earth? Anthropomorphic Days in Genesis 1:1-2:3," *Presbyterion* 20 (1994): 114.

[197]Discussed above, page 23.

[198]Hooke, *Posthumous Works*, 313–314. Assigned by Rappaport to the first series ending September 15, 1668; Drake, *Restless Genius*, 201.

> This Sphaerical Firmament or Shell then in the middle of the Waters, we may suppose, was in some places raised or forced outwards, and some other parts were pressed downwards or inwards, and sunk lower, when in the ninth Verse, God commanded the Waters under the Heaven to be gathered together to one place, and the dry Land to appear; for by depressing in of some parts of that Sphaerical Shell (to make room to receive all the Waters that had before covered the whole) other parts must be thrust out, the Contents within being the same, and so requiring equal Space or Extension;...[199]

In a second great earthquake, Hooke continued, this process was exactly reversed: the depressed areas were elevated to form dry land, and the elevated areas were depressed to form new seas. Halfway through this reversal, understood as Noah's Deluge, the firmament passed through its original spherical form "as it was at the first Creation" thereby producing a globally universal deluge. If later earthquakes—from Plato's Atlantis to the seventeenth century—were of lesser severity, and if Hooke's views on earthquakes were not completely cyclic, their progression from greater to lesser intensity may owe something to the biblical framework he employed and the exegetical expectations of his audience at the Royal Society. In this regard Hooke's views were far more congenial to orthodoxy than Burnet's, as we shall see, despite the existence of plausible directionalist alternatives which did not entail so great a degree of crustal movement or the utter obliteration of antediluvian geography.[200] But here the point is that the deployment of actors' categories regarding temporal sensibilities, not modern definitions and analytical distinctions, should frame the analysis of natural order and historical contingency. As Lloyd suggests, the initial statement of the idea of contingency is of the greatest importance since once made explicit it could be developed in unforeseen ways,

[199]Hooke, *Posthumous Works*, 414–415. Assigned by Rappaport to series 14, February 29, 1688; Drake, *Restless Genius,* 307–308. Drake's reprint of Hooke's complete lectures on earthquakes according to Rappaport's chronology is most valuable and her introductory chapters are an important contribution to Hooke scholarship, but her marginal comments to Hooke's text are often disappointingly Whiggish and misleading. Nowhere is this more so than when Hooke engages in the explication of scripture. Although Drake regards Hooke's exegetical interpretations as forced and contorted exercises, they were actually quite conventional among his contemporaries, as we shall see in chapter 5.

[200]Josephus and the tranquil flood theory based upon antediluvian geography are briefly discussed on page 524.

and from the initial hexameral context the idiom of successive, contingent days was later translated into more modern contexts.

Providential History as Cyclic or as a Predetermined Unfolding of Events

Oldroyd objects that a historical sensibility is incompatible with Hooke's beliefs that history unfolds according to some inspired plan. Part of the problem here is the observation that apocalyptic doctrines were often cyclical, and indeed there are strong cyclical elements in Hooke's vision of the Earth's past.[201] As with the cyclical revolutions of astrological prophecies, however, cyclic elements were often superimposed upon a linear progression and do not rule out a significant mixture of genetic and historical sensibilities.[202] A more fine-grained analysis is necessary which allows for the simultaneous holding of apparently contrary beliefs.

On the other hand, part of Oldroyd's objection here seems to be the common assumption that for some reason, by definition, millenarian and providential conceptions of history must be genetic and deterministic rather than contingent. Yet Christian theology had long tangled with the thicket of divine foreknowledge of future contingents, and it was perfectly orthodox to insist that prophetic fulfillment occurs despite the fact that the foretold events could have turned out otherwise (that is, that events occur contingently rather than being determined in and of themselves—thus the need for supernaturally-inspired prophecy in the first place).[203] Orthodox Christians—even not so orthodox figures like Isaac Newton who nevertheless held to predestination and prophecy—could also reject historical determinism by

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[201]These cyclical elements in Hooke's Theory are emphasized in David Charles Kubrin, "Providence and the Mechanical Philosophy: The Creation and Dissolution of the World in Newtonian Thought. A Study of the Relations of Science and Religion in Seventeenth Century England" (Ph.D. dissertation, Cornell University, 1968); and Yushi Ito, "Hooke's Cyclic Theory of the Earth in the Context of Seventeenth Century England," *British Journal for the History of Science* 21 (1988): 295–314.

[202]In her review of recent discussions of astrological conceptions of history, Smoller warns that it is "misleading" to "stress the cyclical as opposed to linear nature of astrological history." Laura Ackerman Smoller, *History, Prophecy, and the Stars: The Christian Astrology of Pierre D'Ailly, 1350–1420* (Princeton: Princeton University Press, 1994), 81. On cyclic and linear components of temporal sensibilities see footnote 44 on page 26.

[203]Cf. William Lane Craig, *The Problem of Divine Foreknowledge and Future Contingents from Aristotle to Suarez* (Leiden: E. J. Brill, 1988).

means of the doctrine of "particular providence," enjoined among the devout as an obligatory object of meditation and constant topic of conversation. Particular providence was routinely deployed in the seventeenth century to explain unexpected turns of fate and the unpredictable vicissitudes of life (such as the English interpretation of the defeat of the Spanish armada). And few Christians ever argued that the Incarnation (however much it was the fulfillment of prophecy) resulted from the necessary action of general causes.[204] The examples of divine foreknowledge of future contingents, the practice of meditation upon particular providences, and the doctrine of the Incarnation itself illustrate that for believers in God's absolute power and omnipotence, history consisted of unique and utterly novel events.[205] But surely, just as with geology, one should not expect a given vision of Earth history during the seventeenth and eighteenth centuries to be either completely contingent or completely lawbound, either utterly chaotic or rigidly deterministic. Merely developmental aspects (and even nontemporal structural concerns) are sometimes most prominent in early nineteenth-century geology. And

[204]To the contrary, the doctrine of *creatio ex nihilo*—the second-most significant unique event envisioned by Christian theology—developed in the course of early church discussions of the uniqueness of the Incarnation; cf. Thomas F. Torrance, *Divine and Contingent Order* (Oxford: Oxford University Press, 1981). The compatibility between historical contingency and particular providence is also evident in the voluntarist doctrinal tradition studied by Oakley and Osler; Francis Oakley, *Omnipotence, Covenant, and Order: An Excursion in the History of Ideas from Abelard to Leibniz* (Ithaca: Cornell University Press, 1984), and Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994). Perhaps Oldroyd's analysis relies chiefly upon nineteenth-century formulations of *general* providence in which its genetic character was emphasized; cf. Charles Coulston Gillispie, *Genesis and Geology: A Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790–1850* (Cambridge: Harvard University Press, 1951); but particular providence still played a significant role, for example, in the arguments of William Whewell against the plurality of worlds on the basis of geological history (discussed further in chapter 6).

[205]This claim is also briefly illustrated from theological passages in a classic source: arguing against the idea of infinite cosmic cycles and the eternity of human existence, in *The City of God* Augustine supposed that by his will God could "keep on endlessly creating one new and dissimilar thing after another." Thus he was able to create all of humanity in a flow of history starting with Adam; cf. Book XII, especially chapter 19. Augustine's emphasis here upon providential history as consisting of unique and novel events is similar to his argument against Platonist views of the eternity of the world in Book XI, chapter 4. Platonists reasoned that the world must be eternal lest God act rashly by creating the world at an arbitrary time, thus introducing novelty without sufficient reason. Augustine responded by asking how this conclusion was consistent with their belief in the possibility of the soul's escape from misery. The escape of the soul from misery would be an absolutely novel event in the existence of that soul, just the sort of occurrence which they rejected as impossible with respect to the creation. Thus Augustine's emphasis on the will of God allowed him to envision unique and novel events as not only conceivable, but as intelligible and comprehensible, and as providing a foundation for a providential view of history. Such voluntarist traditions of providence—especially later emphases upon particular providence—though eschewing the nescience associated with chance, meet the definition of contingency given in footnote 1 on page 7. How doctrines of particular providence may have shaped attitudes regarding contingent events in the history of the Earth requires further study.

historical aspects do in fact surface in Hooke's writings, sometimes quite markedly, as Oldroyd himself has recently conceded. The evidence of Oldroyd's about-face shows that one must weigh both aspects along a sliding scale, against the backdrop of a continuum of contemporary positions, to assess the relative degree of historical contingency in any given Theory.[206]

Conclusion

Oldroyd is surely right to point to the significant contribution of German Historicism to sensibilities about the Earth, and we must leave for another occasion an adequate consideration of the particularities of Hooke's temporal sensibilities as they developed over his career, but this discussion suggests it is past time for debating where and when historical thinking originated once and for all, carried on by partisans of one episode or another. Rather, for historians to explore the complexities of historical thinking about the Earth in a variety of places, times, and contexts promises much more illumination. The current state of historiographical discussion on the question of historical thinking in Theories of the Earth bears some parallels with trends for other discussions: Instead of insisting on the rather simplistic thesis that

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[206]In a more recent article Oldroyd suggests that in the late 1680s Hooke's views became directionalist; David R. Oldroyd, "Geological Controversy in the Seventeenth Century: 'Hooke vs. Wallis' and its Aftermath," in *Robert Hooke: New Studies*, ed. Michael Hunter and Simon Schaffer (Woodbridge, Suffolk: Boydell Press; Rochester, NY: University of Rochester, 1989), 207–234. Oldroyd writes (p. 226): "The legend of the four ages of the world... suggested a directional Earth history.... This conflicts with the standard interpretation of Hooke's theory as stated in 1686 and 1687, which is seen as cyclic, arising from a (presumably) continuous and continuing process of axial displacement relative to the Earth's surface. However... Hooke was at pains to show that he did not envisage repeated episodes of exposure and submergence." Again (p. 231): "Hooke's theories... were both diverse and extensive.... the diversity of his views was such that even quite recent accounts of them have conflated disparate elements and do not give a very clear or accurate picture. We can see elements that are both 'catastrophist' and 'uniformitarian'; cyclical and directionalist; naturalistic and physico-theological; chemical, physical, and historical." Oldroyd's brief treatment of Hooke in his recent survey is also much more balanced, introduced with the following comment: "As might be expected, the process of the emergence of geology from natural history, 'theories of the earth,' etc., began before the term geology was actually coined. And it was a gradual rather than an instantaneous process. We can see early intimations of the process of 'detachment' in England with the work of Robert Hooke (1635-1703), which was quickly followed up by Nicolaus Steno (1638-86) in Italy, and then a number of other Continental writers such as Lehmann, Füchsel and Arduino. The polymathic Hooke... is interesting as a transitional figure in that while offering a 'theory of the earth' in the older sense, he also saw the possibility of reading a 'history' of the globe from its strata and their contents. Moreover, he thought it possible to corroborate his ideas from the mythological and historical information that had been transmitted from antiquity." David R. Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (Cambridge: Harvard University Press, 1996), 60–61. Yet Oldroyd still assumes that Theories of the Earth were a necessarily ahistorical genre of thought, and he still insists that a Foucaultian discursive rupture between the classical and historical epistemes occurred with German Historicism around the turn of the nineteenth century (p. 122).

"external" factors do influence the "internal" development of scientific knowledge, social historians of science have largely moved on to exploring the rich and manifold aspects of their interaction. Instead of arguing that some particular religious tradition explains the rise of modern science, intellectual historians have largely moved on to elucidating the complexity and variety of the interpenetration of seventeenth-century science and religion on many levels.[207] Analogously, instead of pointing to a single episode of historical thinking about the Earth and arguing that it was of exclusive significance, historians of the Earth sciences should move on to more nuanced, multifactorial explorations of the complex, long-term, and piecemeal development of historical thinking about the Earth. Certainly, a reassessment of the tradition of Theories of the Earth plays one role in this exploration.

§ 7. Part I Summary of Historiographical Theses

A panorama of early modern sensibilities regarding the relations between natural order, genetic development, and historical contingency were manifestly contested in Theories of the Earth. This important textual tradition defies formulaic definition, being constituted of a heterogenous assortment of seventeenth- and eighteenth-century works, not limited to those entitled "Theory of the Earth" or even making use of that term, but properly including works so regarded by later writers as having significantly participated in the development of the tradition. No unique *mentality* or *genre of thought* may be attributed to the tradition as a whole, nor were they confined to one or a few *literary* genres. Various interpretations of Theories of the Earth exclusively in terms of the mechanical philosophy, providence, cosmogony, concepts of duration, age, genetic formation, and contingent history, among others, have revealed

[207] Early arguments for the unique influence of particular religious traditions upon the rise of modern science include White (medieval technology); Hooykaas (Reformation theology); Merton (Puritanism). More recent studies have burst the boundaries of these inquiries, refining the original theses almost beyond recognition and tracing interconnections and ramifications far beyond their original contexts: (religious aspects of the control of nature); (broad "voluntarist" tradition rather than Reformation theology *per se*); (Anglican latitudinarianism and Jesuit science as well as Puritanism). It should be noted that these citations are only for the purpose of illustration, and barely sample the burgeoning literature on early modern science and religion.

important aspects of particular works or episodes, but such thematic categories are insufficient by themselves adequately to portray it as an historical tradition. As an overarching general discourse, the textual tradition of Theories of the Earth provided a "public sphere" for the interaction of diverse perspectives from widely varying contexts associated with a multiplicity of technical disciplines.

Traditional accounts of their origin and demise require reassessment on the basis of historiographical models emphasizing the appropriation and transformation of traditions, rather than a strict continuity of research programs displaced in sharp revolutionary breaks by competing paradigms or epistemes. In this light, demarcationist rhetoric of many Theorists and geologists must be critically reassessed. Theories of the Earth, while something other than an incipient geology, cannot be properly understood as a category wholly distinct from, and incommensurable with, early nineteenth-century historical geology. Theories of the Earth overlapped with cosmology but they were not conflated with cosmology nor did they presuppose any specific cosmology, just as they should neither be conflated with geology nor denied an overlap of concerns and engagement with geology.

As these various obstacles to a historical understanding of Theories of the Earth are removed, the way is clear to reaffirm a modest form the Relevance Thesis of Jacques Roger, that Theories of the Earth were not a negligible accident in the development of the Earth sciences, but played a critical role in establishing historical ways of thinking in early modern natural philosophy and the nineteenth-century historical sciences.

PART II

GLOBAL VISIONS: PORTRAITS OF A TRADITION

> If we imagine an observer to approach our planet from outer space, and, pushing aside the belts of red-brown clouds which obscure our atmosphere, to gaze for a whole day on the surface of the earth as it rotates beneath him, the feature beyond all others most likely to arrest his attention would be....
>
> Eduard Suess, *Das Antlitz der Erde*, 1904

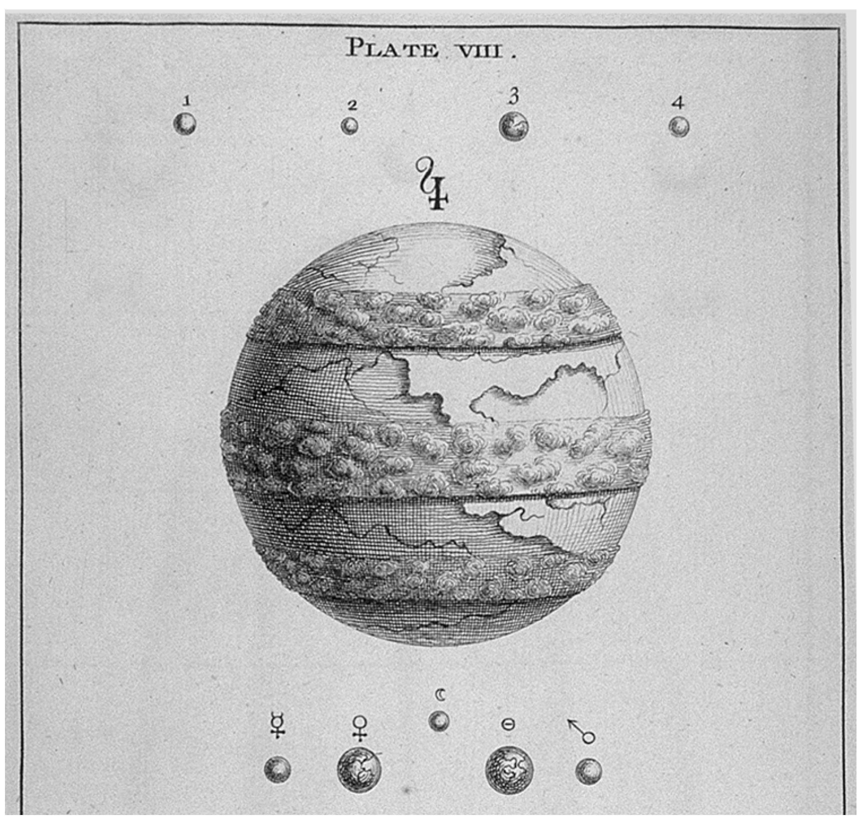

FIGURE 36. Thomas Wright, 1750, *Plate VIII* (top half), Jupiter. HSCI.

CHAPTER 4

Theories of the Earth and Visual Representations

§ 1. Introduction

Theories of the Earth were nothing if not global visions. It is no coincidence that they abound with illustrations of the Earth as a globe. Like photographs of the Earth from the Moon, these illustrations remove us as spectators from the familiar landscapes of our particular localities and launch us into outer space. They enlist the wide perspective of the imagination as a "virtual witness" to the globe as the Theorist represented it.[1] Theorists of the Earth sought to look across vast

[1] The now-common phrase "virtual witness" is used by Rudwick to describe the ways in which visual images enhance the authority of textual claims by making a scene which the reader could not possibly witness seem authentic and immediate. Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992), pp. 1, 255. Rudwick adapted this felicitous phrase from Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), who employed it to refer to the literary means by which Robert Boyle created the impression among his readers that the experimental phenomena he described were real and reliable.

stretches of time as well as through the depths of space, and to carry their readers with them as far as their vision could reach.

In the conclusion to the Part II epigraph, the alpine geologist Eduard Suess suggested that the globe's most significant feature as seen from space would be "the wedge-like outlines of the continents as they narrow away to the South."[2] Although Suess' conclusion echoes the geognostical insight of Alexander von Humboldt,[3] it is not what first springs to mind for twenty-first-century readers who have witnessed Apollo photographs of a blue planet, nearly three-fourths of its surface ocean, covered by white wisps of clouds in a largely transparent atmosphere. However, Suess' rhetoric was masterful, and his comprehensive arguments for a global tectonics rightly persuaded many and galvanized productive geological research in the

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[2] "Könnte ein Beobachter, aus dem Himmelsraume unserem Planeten sich nähernd, die röthlichbraunen Wolkenzonen unserer Atmosphäre bei Seite schieben und die Oberfläche des Erdballes überblicken, wie sie, unter seinen Augen rotirend, sich im Laufe eines Tages ihm darbietet, so würde vor allen anderen Zügen der südwärts keilförmig sich verengende Umriss der Festländer ihn fesseln." Eduard Suess, *Das Antlitz der Erde*, 3 vols. (Prag: F. Tempsky; Leipzig: G. Freytag, 1883-1909), vol. 1, p. 1; epigraph translation from Eduard Suess, *The Face of the Earth*, trans. Hertha B. C. Sollas, 4 vols. (Oxford: Clarendon Press, 1904), vol. 1, p. 1. Throughout the work, Suess repeatedly employed the rhetorical device of imagining an observer descending from space. Suess employed no global sections, but included three global views of the eastern, western, and northern hemispheres; Schematische Gliederung der Erdoberfläche, vol. 3, after p. 790. The engraving accompanying the epigraph is not from Suess, but *Plate VIII* from Thomas Wright, *An Original Theory of the Universe, Founded upon the Laws of Nature, and solving by Mathematical Principles the General Phænomena of the Visible Creation; and Particularly the Via Lactea. Compris'd in Nine Familiar Letters from the Author to his Friend. And Illustrated with upwards of Thirty Graven and Mezzotinto Plates, By the Best Masters* (London: Printed for the Author, and sold by H. Chapelle, in Grosvenor-Street, 1750), hereafter "Wright, *Original Theory.*" There are many consonances and overlaps between Theories of the Earth and theories of the universe, as one might gather from an inspection of this engraving—note the continental outlines beneath the (presumably) red-brown atmospheric bands of Jupiter. Wright's work is often regarded as the beginning of modern ideas about the arrangement of stars in the Milky Way, and it displays numerous consonances with early English Theories of the Earth; cf. Michael A. Hoskin, "The English Background to the Cosmology of Wright and Herschel," in *Cosmology, History and Theology,* ed. W. Yourgrau and A. Breck (New York: Plenum Press, 1977), 219–232.

[3] Humboldt cited Francis Bacon and Reinhold Forster as drawing the attention of geographical observers to the pyramidal shape of the southern tips of continents, and Humboldt regarded this configuration as signs of a former scouring out by means of a catastrophic torrent arising from the south. Alexandre von Humboldt, "Esquisse d'un Tableau Géologique de l'Amerique méridionale," *Journal de Physique* 53 (1801): 33–34; cf. Alexander von Humboldt, *Cosmos: A Sketch of the Physical Description of the Universe,* trans. Elise C. Otté, vol. 1, 4 vols. (1845; Baltimore: Johns Hopkins University Press, 1997), 290–293. Carozzi summarizes: "Cette idée paroît moins hasardée lorsqu'on envisage l'ancien et le nouveau continens comme séparés par la force des eaux. La forme des côtes, les angles rentrans et saillans de l'Amerique, de l'Afrique et de l'Europe, annoncent cette catastrophe; ce que nous nommons océan atlantique n'est qu'une *vallée creusée* par la force des eaux. La forme pyramidale de tous les continens dont la pointe est dirigée au sud, le plus grand aplatissement du globe au pôle austral, et d'autres phénomènes observés par M. Reinhold Forster paroissent prouver que l'impulsion des eaux venoit du sud." Albert V. Carozzi, "À Propos de l'Origine de la Théorie des Dérives Continentales: Francis Bacon (1620), François Placet (1668), A. von Humboldt (1801) et A. Snider (1858)," *Comptes Rendu des Séances de la Société de Physique et d'Histoire Naturelle de Genève,* nouvelle série 4 (1969): 175.

late nineteenth century. To express the broad scope of their global visions a century and more before Suess, and up to three centuries before the first Apollo photographs, Earth Theorists drew attention to the features of the globe that they believed held great significance for a similarly comprehensive understanding of the Earth. These features were often emphasized in visual illustrations.[4]

Historians of science such as Martin Rudwick, Kenneth L. Taylor, Rhoda Rappaport, and others have provided superb analyses of the development of geological maps in the late eighteenth century and early nineteenth century.[5] Other studies have examined aesthetic qualities of a variety of artistic landscape and topography depictions, and Rudwick has interpreted nineteenth-century representations of prehuman landscape scenes.[6] However, no sustained

4 Throughout this study I refer to the authors of the texts as if they were the authorizers of the visual representations. This does not overlook the fact that artists, engravers, and printers were critically involved in the production of the images. Steven Shapin has pointed out the cultural significance of "invisible artisans"; see Steven Shapin, "The Invisible Technician," *American Scientist*, 1989, 77: 554–563. To consider adequately the artisans involved in the production of any of the engravings discussed would be fruitful but require separate studies. It is enough for the present purpose to consider how the published work was *read*, and this requires, for the most part, only that the illustrations analyzed were clearly referred to and explicitly discussed by the authors in the texts accompanying them. If this is so, however, one may assume that the images were not produced independently of the author or included without authorial consent. Many of the illustrations discussed are copper engravings which depict much finer detail than woodcuts. Since engravings were produced at considerable expense, their presence may reflect authorial sanction for their major features. On the early development and practices of print technologies in the earth sciences see Martin J. S. Rudwick, "The Emergence of a Visual Language for Geological Science, 1760–1840," *History of Science*, 1976, 14: 149–195 (hereafter "Rudwick, 'Visual Language'), section 2, "Materials and Techniques," 152–158.

5 On geoscience mapping and related visual representations see Rudwick, "Visual Language"; Kenneth L. Taylor, "Early Geoscience Mapping, 1700–1830," *Proceedings of the Geoscience Information Society*, 1985, 15: 15–49; Rhoda Rappaport, "The Geological Atlas of Guettard, Lavoisier and Monnet: Conflicting Views of the Nature of Geology," in *Toward a History of Geology*, ed. Cecil J. Schneer, 272–287 (Cambridge: MIT Press, 1969). More recently cf. Susanne B. Keller, "Sections and Views: Visual Representation in Eighteenth-Century Earthquake Studies," *British Journal for the History of Science* 31 (1998): 129–159. *Earth Sciences History*, volume 14, Number 1, 1995, features articles on visual thinking in nineteenth and twentieth-century geology.

6 An interesting discussion of early modern landscape painting is Scott L. Montgomery, "The Eye and the Rock: Art, Observation and the Naturalistic Drawing of Earth Strata," *Earth Sciences History* 15 (1996): 3–24. See also Marie Thompson and Jan Kozak, "Images des Tremblements de Terre du Passé," in *L'Image et la Science: Sections d'archéologie et d'histoire de l'art, d'histoire des sciences et des techniques, et des sciences,* ed. Paul Rossignol and Roger Saban, Actes du 115e Congrès National des Sociétes Savantes, Avignon, 1990 (Paris: Editions du C.T.H.S., 1992), 53–65; and Charlotte Klonk, *Science and the Perception of Nature: British Landscape Art in the Eighteenth and Early Nineteenth Centuries* (New Haven: Yale University Press, 1996). On prehuman representation see Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992). For nineteenth-century depictions see also Karen Wonders, *Habitat Dioramas: Illusions of Wilderness in Museums of Natural History* (Uppsala: Almqvist and Wiksell, 1994). Twentieth-century cinematic representations of wilderness scenes are insightfully explored in Gregg Mitman, *Reel Nature: America's Romance with Wildlife on Film* (Cambridge: Harvard University Press, 1999).

analysis of seventeenth- and eighteenth-century global sections and views has appeared. Representational conventions from astronomy and cosmology,[7] geography,[8] anatomy[9] and other disciplines provided important precedents for the development of global sections and views by which seventeenth-century Theorists were able more effectively to convey their visions of the Earth. For example, conventions for cosmological and geographical illustrations merged in the production of maps of new worlds. In this way the Moon served as an analogue for the Americas, as Scott Montgomery has shown in a brilliant study of the development of visual representations of the Moon through the seventeenth century. Montgomery observes that "Until quite recently, maps were much larger documents than they are conceived of today. They were places where a profound merger took place among art, science, mathematics, politics, and religion."[10] The same was true of global illustrations in Theories of the Earth and, as we shall see, in critical ways the Moon set a pattern not only for imagining other planets, but also for representing the Earth and its past.[11]

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7 Relevant studies of astronomical and cosmological imagery include M. T. d'Alverny, "Le Cosmos Symbolique du XIIe Siècle," *Archives d'histoire doctrinale et littéraire du moyen âge* 28 (1953): 31–81; S. K. Heninger, Jr., *The Cosmographical Glass: Renaissance Diagrams of the Universe* (San Marino, California: Huntington Library, 1977); Danielle Lecoq, "L'Image de la Terre a Travers les Écrits Scientifiques du XIIe Siècle: Une Vision Cosmique, Une Image Polémique," in *L'Image et la Science: Sections d'archéologie et d'histoire de l'art, d'histoire des sciences et des techniques, et des sciences,* ed. Paul Rossignol and Roger Saban, *Actes du 115e Congrès National des Sociétes Savantes,* Avignon, 1990 (Paris: Editions du C.T.H.S., 1992), 15–37; Kristin Lippincott, "Giovanni di Paolo's 'Creation of the World' and the Tradition of the 'Thema Mundi' in Late Medieval and Renaissance Art," *Burlington Magazine* 132 (1990): 460–468; Deborah J. Warner, *The Sky Explored: Celestial Cartography, 1500–1800* (New York: Alan R. Liss, 1979). Studies of visual representations pertaining to Galileo's astronomical discoveries are cited below; see "The Natural Face of a Wrecked and Ruined World," beginning on page 486.

8 Relevant studies of geographical imagery include James S. Romm, *The Edges of the Earth in Ancient Thought: Geography, Exploration, and Fiction* (Princeton: Princeton University Press, 1992); Barbara Maria Stafford, *Voyage into Substance: Art, Science, Nature, and the Illustrated Travel Account, 1760–1840* (Cambridge: MIT Press, 1984).

9 Relevant studies of anatomical imagery include Charles Clark, "The Zodiac Man in Medieval Medical Astrology," *Journal of the Rocky Mountain Medieval and Renaissance Association* 3 (1982): 13–38; Martin Kemp, "Temples of the Body and Temples of the Cosmos: Vision and Visualization in the Vesalian and Copernican Revolutions," in *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science,* ed. Brian S. Baigrie, Toronto Studies in Philosophy (Toronto: University of Toronto Press, 1996), 40–50;

10 Scott L. Montgomery, *The Moon and the Western Imagination* (Tucson: University of Arizona Press, 1999), 7. Hereafter, "Montgomery, *The Moon.*"

Theories of the Earth were an historically contingent and conceptually heterogenous tradition; it is not surprising that in early Theories a wide variety of illustrations were deployed in diverse and contrasting ways. Moreover, as visual conventions developed, the durability of some forms of visual representation manifested the existence of an established tradition of textual debate; similar illustrations embodying strong threads of continuity were even used to serve contradictory ends. Of course, global sections and views cannot be regarded as essential to the tradition as a whole. Some major Theories, such as John Woodward's, were first printed in inexpensive editions without so much as a frontispiece.[12] No depictions of the globe are found in the Theories of James Hutton or Abraham Gottlob Werner, arguably the two most important Theorists of the late eighteenth century.[13] Global sections may appear in works that are not Theories of the Earth at all.[14] Yet global sections and views first came into widespread didactic use in the Theory of the Earth tradition.

A few major characteristics of these illustrations, particularly the relations of global sections and views to cosmic sections and the hexameral tradition, are introduced in the remainder of this chapter, but first we should note a clarification of terms. Some modern readers

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11 Montgomery notes that "As its nearest and most observable neighbor, the Moon became the Earth's alter ego in the Western imagination, and in turn, exerted its influence on the rest of the solar system. The lunar face proved itself the sometime standard for even the Sun, as shown by an engraving in Kircher's *Iter exstaticum*, which depicts the solar surface full of round, flaming craters from which black clouds of smoke (sunspots) emerge. The Moon did not merely set a pattern; it created predispositions that awoke each time 'discovery of place' was reenacted in the heavens." Montgomery, *The Moon,* 217–218. The significance of the precedent of lunar depictions for representing the Earth is discussed below with respect to Thomas Burnet; see "Crustal Collapse: The Early Modern Platonic Paradigm," beginning on page 474.

12 One "Woodwardian" global section was added to a French translation of Woodward's Theory (see "Mosaic Theories: Fossil Emplacement by Diluvial Dissolution," beginning on page 641). John Woodward, *An Essay toward a Natural History of the Earth: and Terrestrial Bodies, Especially Minerals: As also of the Sea, Rivers, and Springs. With an Account of the Universal Deluge: And of the Effects that it had upon the Earth* (London: Printed for Ric. Wilkin, 1695).

13 At least one Huttonian and one Wernerian employed global sections, however (see "Huttonian Sensibility: A Non-Historical Natural Order," beginning on page 725, and "Amos Eaton, Fieldwork, and Wernerian Geognosy," beginning on page 695). Yet global sections are absent in James Hutton, *Theory of the Earth, with Proofs and Illustrations*, 2 vols. (Edinburgh: for Cadell and Davies, London, 1795); and Abraham Gottlob Werner, "Kurze Klassifikation und Beschreibung der Verschiedenen Gebirgsarten," *Abhandlungen der Böhmischen Gesellschaft der Wissenschaften* 2 (1786).

14 Cf. Herbert R. Shaw, *Craters, Cosmos, and Chronicles: A New Theory of the Earth* (Stanford: Stanford University Press, 1994). Shaw uses more than fifty schematic diagrams of the globe to discern large-scale patterns over time, in the process claiming that he couples Earth history and cosmic history in a way Hutton would not have found repugnant (317).

lump together the global depictions found in Theories of the Earth and regard them as "cosmogonic sections," a conceptually limited and occasionally misleading term. In particular, the word "cosmogonic" shares the ambiguities of "world" (*cosmos* in Greek, *mundus* in Latin). All three terms may refer to at least five different things: the universe, a solar system (or vortex), the Earth itself, any Earth-like planet, or sometimes even a region such as a continent or the known world. Thus, in a strictly literal sense, one may speak of geogony as cosmogony, or geology as cosmology.[15] However, disregarding archaic usages for the sake of clarity, I will restrict the prefix *cosmo-* to the first two meanings, so that "cosmogonic" as I use it refers to the origin of the universe or solar system. "Geogonic" will be reserved for the origin of the Earth or an Earth-like planet only. Additionally, "cosmogonic section" is not apt, because global views are not sections. Finally, just as not all cosmic sections were cosmo*gonic*, similarly, not all global sections depicted geo*gonic* processes (some portrayed static or dynamically stable geophysical systems). Since descriptive phrases are preferable to archetypal shorthand, better terms are "global section" to refer to cut-away diagrams of the Earth's inner structure, and "global view" to refer to depictions of its surface.

§ 2. Global Sections

Global sections portray the entire globe, or at least a pie-slice portion cut out of the globe, extending from the surface down perhaps to the core. In *Voyage au Centre de la Terre* (1864) Jules Verne's protagonist, the mineralogy professor Otto Lidenbrock, repeatedly takes compass measurements and performs calculations because, as he says, "When we've come back, I want to be able to draw a map of our journey—a kind of vertical section of the globe that will show the course of our expedition."[16] Verne's fictional mineralogy professor undertook his voyage of exploration in part to confirm the theory of the British chemist Humphry

[15] In this archaic sense Hutton referred to his own fieldwork as establishing a cosmogony; see page 125.

Davy, and by drawing an accurate global section during the journey, Lidenbrock believed he would be able to prove it once and for all.

In the first decade of the nineteenth century, Davy used electrolysis techniques to prepare pure samples of alkaline metals such as potassium, sodium and calcium. Davy showed that in solid unreacted form, these metals vigorously combust on mere contact with water, and from 1808 he suggested that such metals might comprise the Earth's interior. On contact with subterraneous bodies of water, their combustion might fuel deep-seated volcanos. This would make it unnecessary to postulate an ever-increasing temperature as one moves deeper toward the Earth's core—obviously, a prerequisite for fictional voyages such as Professor Lidenbrock's, who was able to affirm on his return that "Humphry Davy was right."[17]

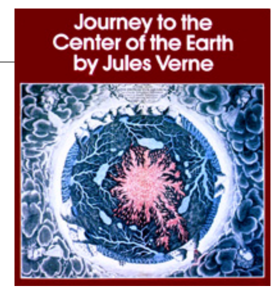


FIGURE 37. Illustrated cover of Jules Verne, *Journey to the Center of the Earth* (New York: Bantam Books, 1991).

That Theories of the Earth held a popular appeal even through the nineteenth century is reflected in the success of Verne's novels. The prospect of discovering a true Theory of the Earth animated the characters and provided

[16] "D'abord, dit-il, je vais faire des calculus, afin de relever exactement notre situation; je veux pouvoir, au retour, tracer une carte de notre voyage, une sorte de section verticale du globe, qui donnera le profil de l'expédition." Jules Verne, *Voyage au Centre de la Terre*, Collection Hetzel (Paris: Librairie Hachette, 1926), Ch. XXV, p. 192; translation by Lowell Blair, *Journey to the Center of the Earth* (New York: Bantam Books, 1991), p. 133. No global sections exist in this 1926 edition of *Voyage*; I have not been able to examine nineteenth-century editions for global illustrations.

[17] Davy claimed to have delivered the first geology lectures in London, and in them he spoke of his attempt to develop a "perfect chemical theory of the globe"; *Humphry Davy on Geology: The 1805 Lectures for the General Audience,* ed. Robert Siegfried and Robert H. Dott, Jr., (Madison: University of Wisconsin Press, 1980), 59. Averse to overspecialization, Davy shared with most of his contemporaries a directionalist perspective of Earth history and maintained a key interest in Huttonian and Neptunian debates. An example of his mature chemical theory of volcanos and the interior of the globe is found in "On the Phenomena of Volcanoes," a report of his visit to Vesuvius published in the *Philosophical Transactions* for 1828 and reprinted as Humphry Davy, "On the Phenomena of Volcanoes," in *Miscellaneous Papers and Researches,* ed. John Davy, vol. 6 of *Collected Works*, 9 vols. (London: Smith, Elder and Co., 1839–1840), 344–358. (However, the last paragraph of this essay anticipates Davy's posthumously-published retraction of his chemical theory.) Cf. Robert Siegfried and Robert H. Dott, "Humphry Davy as Geologist, 1805–1829," *British Journal for the History of Science* 9 (1976): 219–227, and David Knight, *Humphry Davy: Science and Power* (Oxford UK and Cambridge USA: Blackwell Publishers, 1992). Cf. Kenneth L. Taylor, "New Chemistry and Volcanology: Chemical Theories of Volcanic Action, 1790–1830," paper presented at the meeting of the History of Science Society, Dallas, 1977.

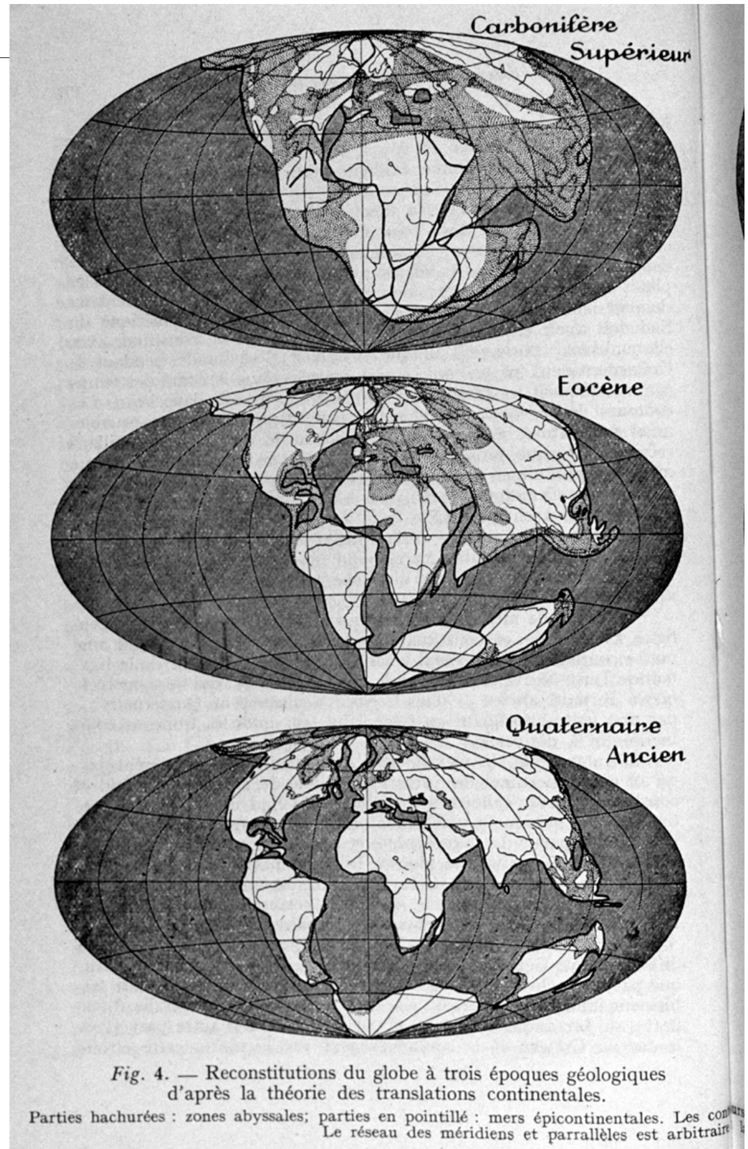
the backdrop for the events narrated in *Journey to the Center of the Earth*.[18] A recent paperback edition of Verne's tale displayed on its cover, without attribution, a magnificent global section from Athanasius Kircher's *Mundus subterraneus,* published 200 years before Verne's *Voyage aux la Centre de la Terre* (Figure 37).[19] This fortuitous pairing of Kircher and Verne conveniently frames, across two centuries, the widespread use of global sections. In Chapter 5, "Textual Assimilation: The Sacred Theory of Burnet," we shall explore how such global depictions arose, and how in the seventeenth century they became associated with Theories of the Earth.

[18] I do not wish to imply that either Davy or Verne were Theorists of the Earth. Pre-occupation with demarcationist arguments (pro or con) distracts attention from the fact that Davy's theory was regarded as a contribution to the Theory of the Earth tradition by some readers (including Verne). Mid-nineteenth-century readers recognized some aspects of Theories of the Earth as a significant context for Verne's works. The hollow-Earth Theories of Edmond Halley and his many successors were held dear by Verne (see "Magnetic Theories of the Earth," beginning on page 631). Therefore, by the second and third textual criteria outlined in Part I, Davy and Verne lie at least on the margin of the tradition. On the other hand, an artificially-narrow and restricted definition of "Theory of the Earth" is necessary to support the proposition that Theories of the Earth abruptly vanished in the early nineteenth century. However, rather than debating labels it is more beneficial to observe that Davy was a technical chemist, yet the relevance of his works to geological topics was widely known; Verne was not a professional scientist, yet his fiction reflected popular demand for scientific understanding: thus both writers in different ways reflect the changing relations between textual and technical traditions in nineteenth-century science (see "Textual versus Technical Traditions," beginning on page 79).

[19] Lowell Blair, trans., *Journey to the Center of the Earth* (New York: Bantam Books, 1991). The section is a colored version of Kircher's hydrophylacia section; cf. Figure 140 on page 537.

§ 3. Global Views

FIGURE 38. Wegener, breakup of Pangaea



Global views display the surface of the Earth, revealing large-scale patterns of the crust. It is no surprise that they have been prominently deployed by geological theorists in the last century. For example, following the lead of the merely verbal "global views" conjured in the rhetoric of Suess, Alfred Wegener (1880-1930) employed printed global views to argue for the former existence of a *Pangaea* supercontinent (Figure 38).[20] All global views, even views of the Earth from space before the Appollo photographs, depend on complex inferences, and many suggest visions of the past. For example, Figure 38 is a cartographic

[20] On Suess, see the epigraph to Part II, "Global Visions," on page 366, and the explanation in footnote 2 on page 368. Cf. Alfred L. Wegener, *Die Enstehung der Kontinente und Ozeane* (Braunschweig: F. Vieweg & Sohn, 1922); the first edition was published in 1915. Figure 38 is from Alfred L. Wegener, *La Genèse des Continents et des Océans: Théorie des Translations Continentales* (Paris: Librairie Nizet et Bastard, 1937); this edition is a translation of the fifth and final German edition. An accessible English version is Alfred Wegener, *The Origin of Continents and Oceans*, trans. John Biram (New York: Dover, 1966), based upon the fourth revised German edition of 1929.

projection intended to minimize distortions inherent in views from space, and it reconstructs changes which took place long before any human eyewitnesses were present upon the Earth to observe them. Wegener described the starting point of his complex inference to drift theory as the supposition that:

> South America must have lain alongside Africa and formed a unified block which was split in two in the Cretaceous; the two parts must then have become increasingly separated over a period of millions of years like pieces of a cracked ice floe in water. The edges of these two blocks are even today strikingly congruent.... A pair of compasses and a globe will show that the sizes are precisely commensurate.[21]

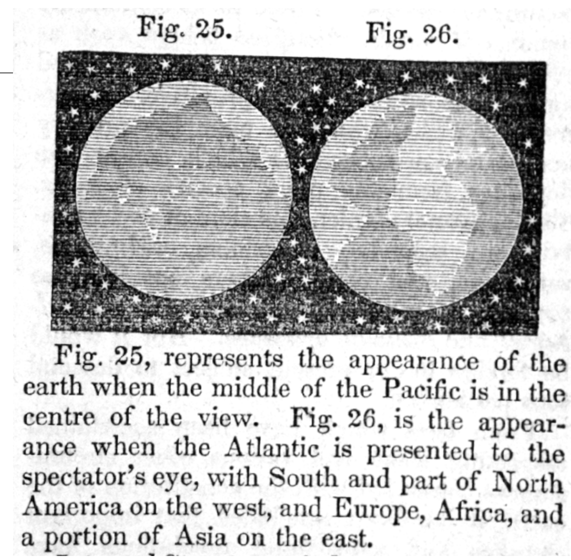


FIGURE 39. Thomas Dick, *Celestial Scenery*, 1847
Rotating Earth viewed from space (HSCI)

Before Suess and Wegener, however, and long before Apollo photographs of the Earth from space, Theorists of the Earth became accustomed to reflecting on how surface conditions of the crust would appear to an imaginary space traveller. Two such global views were published in an early nineteenth-century popular work by Thomas Dick, appropriately entitled *Celestial Scenery*. Dick purported to survey the global views enjoyed by inhabitants of other planets in our solar system. Employing a thought experiment similar to that of Eduard Suess half a century later, Dick imagined how an observer in space or on the Moon, viewing the Earth turning in place, would distinguish the oceans and continents. But for Dick, writing a popular work of cosmology, the scenes were actually beheld by real inhabitants of the

[21] Alfred L. Wegener, *The Origin of Continents and Oceans* (New York: Dover, 1966), 17.

Moon and planets. These extra-terrestrials would surely note a "striking correspondence," Dick believed, between the coastlines of America and Africa:

> A consideration of these circumstances renders it not altogether improbable that these continents were *originally conjoined*, and that, at some former physical revolution or catastrophe, they may have been *rent assunder* by some tremendous power, when the waters of the ocean rushed in between them, and left them separated as we now behold them.[22]

Possibly Dick had in mind merely the common eighteenth-century idea of salient and re-entering angles (proposed by Louis Bourguet), such that a torrent carved a wide ocean channel through a vast primeval continent leaving corresponding angles on either shore. But more likely he meant that a global catastrophe had torn apart an original continent. Dick suggested that the "originally conjoined" continent fractured in two and the resulting fragments were "rent assunder" by the onrushing waters. At present the Earth, thus ruined by Noah's flood, no longer presents a pristine state to the watching inhabitants of other planets (Figure 39).[23]

The differences between the global views of Thomas Dick and Alfred Wegener go far beyond the evident contrast in precision and quality of the depictions. Dick's was a popular work in the cosmological tradition of Plurality of Worlds, a sister textual tradition to Theories of the Earth. Dick's views rested on theological principles of plenitude and divine purpose in the world. Other writers came to similar conclusions on the basis of evidence from classical texts (such as Plato's legend of Atlantis[24]), scripture and geography (e.g., Abraham Ortelius,[25]

[22] Thomas Dick, *Celestial Scenery; or, The Wonders of the Planetary System Displayed; Illustrating the Perfections of the Deity and a Plurality of Worlds* (Hartford: Published by Sumner & Goodman, 1847), 50, italics added (originally published in 1838). Alan Goodacre was the first to point to Thomas Dick as an early writer to envision a separation of continents, "Continental Drift," *Nature* 354 (1991): 261. Comparing Dick to Wegener, John McPhee quips: "Of the two, Dick fared better, for... his proposition achieved no significant attention." John McPhee, *Assembling California* (New York: Farrar, Straus and Giroux, 1993), 102; this passage is deleted in the revised version that appears as Book 4 of John McPhee, *Annals of the Former World* (New York: Farrar, Straus and Giroux, 1998), 492. On Dick's place within the Plurality of Worlds tradition see Michael J. Crowe, "A History of the Extraterrestrial Life Debate," *Zygon* 32 (1997): 147–162.

[23] See footnote 25 for one precedent for suspecting that the continents pulled apart shortly after the Deluge.

[24] See "Platonic Theories of the Earth," beginning on page 175.

[25] James Romm identified an obscure passage in a geographical work by Abraham Ortelius (1527–1598) which endorsed a separation of the continents in the days of Peleg after the Deluge; cf. James Romm, "A New Forerunner for Continental Drift," *Nature* 367 (1994): 407–408. On Ortelius see Cornelis Koeman, *The History of Abraham Ortelius and His Theatrum Orbis Terrarum* (Lausanne: Sequoia, S. A., 1964).

François Placet,[26] and Antonio Snider-Pellegrini[27]). In contrast, Wegener wrote his meteorologist father-in-law: "I believe that you consider my primordial continent to be a figment of my imagination, but it is only a question of interpretation of observations. I came to the idea on the grounds of the matching coast-lines but *the proof must come from geological observations*."[28] On the continuum between cosmology and geology were Theorists of the Earth who said the same.[29] Global sections and views manifest various commitments on questions such as what counted as relevant evidence and which kinds of evidence were most important.

[26] Rather than a separation or drift of continents, Placet envisioned a sinking down of what is now the Atlantic Ocean at the Deluge, thus separating the New World from the Old but without horizontal movements of the crust: "En conclusion, le Père Placet considère le Déluge responsable de la formation du continent américain. Il interprète ce dernier comme le résultat d'un soulèvement engendrant une grande île, parmi tant d'autres, et qui a été compensé par l'effondrement de l'Ile Atlantique, devenue elle-même un océan. Comme dans le cas de Francis Bacon, aucune idée de dérive continentale n'entre en ligne de compte dans cette hypothèse qui, n'exigeant que des mouvements verticaux, répond tout à fait à l'esprit de l'antiquité classique." Albert V. Carozzi, "À Propos de l'Origine de la Théorie des Dérives Continentales: Francis Bacon (1620), François Placet (1668), A. von Humboldt (1801) et A. Snider (1858)," *Comptes Rendu des Séances de la Société de Physique et d'Histoire Naturelle de Genève,* nouvelle série 4 (1969): 174. Cf. R. P. François Placet, *La Corruption du Grand et du Petit Monde, où il est montré, que toutes les Creatures qui composent l'Vnivers, sont corrompuës par le peché d'Adam. Que le Soleil a perdu sept fois plus de lumieres qu'il n'en possede. Que Nouvelle-Lune, estoit pleine-Lune en la Iustice originelle; & qu'elle estoit égale en lumiere au Soleil d'aujourd'huy. Qu'il n'a point plû ny neigé sur la Terre avant le Deluge. Qui devant le Déluge, l'Amérique n'éstoit point séparée des autres parties du Monde, & qu'il n'y avoit aucune Isle dans la Mer. Que le Feu qui consumera l'Vniverse n'aura point d'action sur les Iustes; & qu'il y aura des Hommes vivans sur la Terre, quand Iesvs-Christ viendra iuger le monde, &c,* 3d ed. (Paris: Chez la Veufve Gervais Alliot, & Gilles Alliot, 1668); this Theory of the Earth has not been available to me. Similar vertical movements were postulated by Robert Hooke and Moro, among others. Nicolaas A. Rupke discusses Placet and other alleged precursors of continental drift (Francis Bacon, Theodor Christoph Lilienthal, Alexander von Humboldt, George Darwin) in "Continental Drift Before 1900," *Nature* 227 (1970): 349–350.

[27] As with Dick, Snider-Pellegrini envisioned a horizontal drift of continents, and attributed the separation of the continents to the action of the Deluge. Cf. Antonio Snider-Pellegrini, *La Création et Ses Mystères Dévoilés, Ouvrage où l'on expose... la nature de tous les êtres, les éléments dont ils sont composés... la nature et la situation du feu du Soleil, l'origine de l'Amérique et de ses habitants primitifs, la formation forcée de nouvelles planètes, l'origine des langues, etc.,* (Paris: A. Franck et E. Dentu, 1858). I have not seen this Theory of the Earth, but Carozzi reproduces two global views by Snider-Pellegrini, both far more detailed than Dick's: "Avant la Separation," depicts South America in contact with Africa, and "Aprés la Séparation," shows the Earth in its modern appearance, with the Atlantic Ocean separating Africa and the Americas; Albert V. Carozzi, "À Propos de l'Origine de la Théorie des Dérives Continentales: Francis Bacon (1620), François Placet (1668), A. von Humboldt (1801) et A. Snider (1858)," *Comptes Rendu des Séances de la Société de Physique et d'Histoire Naturelle de Genève,* nouvelle série 4 (1969): 177. Snider-Pellegrini is also discussed in Nicolaas A. Rupke, "Continental Drift Before 1900," *Nature* 227 (1970): 349–350.

[28] Quoted in Anthony Hallam, *Great Geological Controversies,* 2d ed. (Oxford: Oxford University Press, 1989), 153; italics added. One should note, of course, that "geological observations" should be construed broadly, for Wegener relied upon evidence from geophysics, geodesy, paleontology as well as historical geology (as his chapter titles suggest). It is frequently pointed out that Wegener was a meteorologist rather than a geologist. Oreskes shows that many historical geologists rejected his conclusions as allegedly based on non-geological methods; cf. Naomi Oreskes, *The Rejection of Continental Drift: Theory and Method in American Earth Science* (Oxford: Oxford University Press, 1999).

[29] For the case of Jean Andre Deluc see footnote 239 on page 126.

Consequently, by surveying visual representations in Theories of the Earth we will be better able to assess the degree to which their explanations were cosmological or geological or something else unto themselves, and whether they were historical in character or instrumental in shaping the development of historical explanations of the Earth.

§ 4. Visual Aids or Natural Knowledge?

§ 4-i. Ornamental Global Views in Buffon's Histoire naturelle

Historians of science have given greater attention to visual materials in recent years,[30] yet one may still come across those who regard images as superfluous visual aids rather than an important aspect of natural knowledge in their own right. Clearly, some images served primarily ornamental ends, where the accompanying text is fully intelligible without reference to them. Because the ornamental aspects of many illustrations are obvious, despite their memorable character historians often ignore visual representations in textual analysis and neglect their possible significance.[31]

[30] On the need for historians to consider the visual dimensions of the texts they analyze see William M. Ivins, Jr., *Prints and Visual Communication* (London: Routledge and Kegan Paul, 1953); Michael Lynch and Steve Woolgar, eds., *Representation in Scientific Practice* (Cambridge: MIT Press, 1988); Brian S. Baigrie, ed., *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, Toronto Studies in Philosophy (Toronto: University of Toronto Press, 1996); Michael Baxandall, *Patterns of Intention: On the Historical Explanation of Pictures* (New Haven: Yale University Press, 1985); Trevor J. Barnes and James S. Duncan, eds., *Writing Worlds: Discourse, Text and Metaphor in the Representation of Landscape* (London: Routledge, 1992) and Edward R. Tufte, *Envisioning Information* (Cheshire, Connecticut: Graphics Press, 1990). The work of William Ashworth exemplifies the richness of visual materials for historical analysis; e.g. William B. Ashworth, Jr., "Iconography of a New Physics," *History and Technology* 4 (1987): 267–297; and William B. Ashworth, Jr., "Light of Reason, Light of Nature: Catholic and Protestant Metaphors of Scientific Knowledge," *Science in Context* 3 (1989): 89–107. It is no longer unusual to find issues of major journals in science studies devoted to visual representation; cf. *Isis* 84(1993): 637–727, 750–774; *British Journal for the History of Science* 31 (1998), Part 2 (June), "Science and the Visual," ed. J. V. Field and Frank A. J. L. James; Michael Ruse and Peter Taylor, eds., "Special Issue on Pictorial Representation in Biology," *Biology and Philosophy*, 1991, 6: 125–294.

[31] There are also tremendous practical and technological problems inherent in the reproduction of images, which greatly increases the time and expense of publication. I suspect that these practical obstacles were an important factor in the past reluctance of some historians to produce sustained analyses of visual representations, although this has not prevented the ornamental use of illustrations in popular surveys where commercial and pedagogical interests coincide.

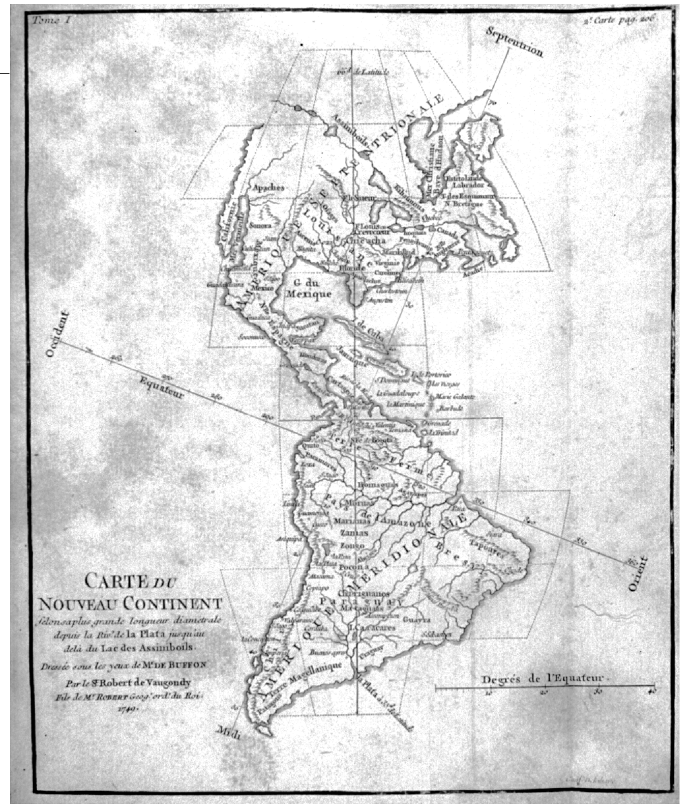


FIGURE 40. Buffon, "Carte du Nouveau Continent"

Buffon offers one example of the use of global views in a purely ornamental fashion. Contrast the cartographic maps in the first volume of Buffon's *Histoire Naturelle* with three ornamental illustrations taken from the same work (Table 44). The cartographic representations—one of the old world (not shown) and one of the new world (Figure 40)—display almost none of the features of ornamental maps. Rather, they reflect Buffon's attempts to discern the regular action of the laws of nature in the configuration of the surface of the Earth, and thereby exemplify Enlightenment conceptions of natural order.[32] In contrast, the illustrations shown in Table 44 were not essentially integrated with the accompanying text, and in subsequent editions they were used to illustrate different passages[33] or—quite unlike the cartographic plates—even omitted.[34]

32 Kenneth L. Taylor, forthcoming. Indispensable studies of Buffon's Theory of the Earth include Jacques Roger, *Buffon: A Life in Natural History*, trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997); Rhoda Rappaport, *When Geologists were Historians, 1665–1750* (Ithaca: Cornell University Press, 1997), Chapter 8; and Kenneth L. Taylor, "The *Époques de la Nature* and Geology During Buffon's Later Years," in *Buffon 88: Actes du Colloque International pour le bicentenaire de la mort de Buffon*, ed. Jean Gayon (Paris: Vrin, 1992), 371–385.

33 The cartographic plates invariably are found either immediately after the table of contents (1750) or, more often, within the article on Géographie in the "Preuves de la Théorie de la Terre." On the other hand, in an 1800 edition Figure 41 and Figure 42 are repositioned, and Figure 42 is even used to illustrate the *Époques de la Nature*; cf. Georges Louis Leclerc Comte de Buffon, *Histoire Naturelle de Buffon, Réduite a ce qu'elle contient de plus instructif et de plus intéressant,* ed. P. Bernard (Paris: Chez Richard, Caille et Ravier, Libraires, An VIII, [1800]), preceding p. 27 and facing p. 49.

TABLE 44. Global Illustrations, Buffon's Natural History, 1749

FIGURE 41. Fissuring Earth

FIGURE 42. Almighty Impulsion

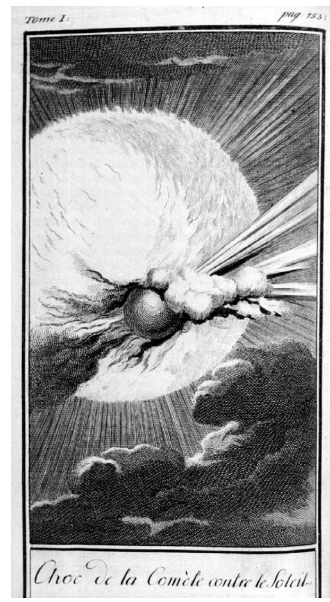


FIGURE 43. "Choc de la Comète contre le Soleil"

Explanation. All three illustrations are found in various editions of the first volume of Georges Louis Leclerc Comte de Buffon, *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi,* originally published in 1749; see footnote 35, footnote 36, and footnote 38.

The engraving shown in Figure 41, which in most editions accompanies the title page of "Histoire & Théorie de la Terre," appears to depict a primeval contraction of dry land with the resulting initial cracking open of the ocean bed.[35] Figure 42, which usually accompanies the title page of "Preuves de la Théorie de la Terre,"[36] represents the propulsion of matter

[34] Figure 41 and Figure 42 were omitted in the first volume of the 1774 edition, which nevertheless contains the two cartographic plates. Cf. Georges Louis Leclerc Comte de Buffon, *Histoire Naturelle, Générale et Particulière,* vol. 1 of *Oeuvres Complètes de M. de Buffon: Théorie de la Terre* (Paris: De L'Imprimerie Royale, 1774).

[35] Georges Louis Leclerc Comte de Buffon, "Second discours: Histoire & Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi,* 36 vols. (Paris: De l'Imprimerie Royale, 1749), vol. 1, facing p. 65 at the beginning of the "Second discours," or "Histoire & Théorie de la Terre."

[36] Georges Louis Leclerc Comte de Buffon, "Preuves de la Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi,* 36 vols. (Paris: De l'Imprimerie Royale, 1749), vol. 1, facing p. 127. While the "Second discours" runs only 60 pages in the 1749 edition, "Preuves de la Théorie de la Terre" continues for nearly 500 pages, comprising nineteen articles devoted to topics such as geography (VI), the tides (XII), and volcanos and earthquakes (XVI). The first five articles are of special historiographical interest in that they contain Buffon's criticisms of earlier Theories of the Earth: Burnet (III), Whiston (II), Woodward (IV), and Steno, Ray, Leibniz, Scheuchzer and Bourguet (all in Article V).

from the Sun resulting in the origin of the solar system. As Buffon remarked early in this essay:

> The force of impulsion was certainly communicated to the planets by the hand of the Almighty, when he gave motion to the universe; but we ought, as much as possible, to abstain in natural philosophy [*en Physique*] from having recourse to supernatural causes, and it apears that within the Solar System one may give a reason for this impulsive force in a probable manner [*manière assez vrai-semblable*], and that one may find a cause producing the effect according to the laws of mechanics, and not by any means more astonishing than the changes and revolutions which may and must happen in the universe.[37]

Figure 43, captioned as the "Choc de la Comète contre le Soleil," illustrates "Preuves de la Théorie de la Terre" in the 1785 edition. It represents the oblique impact upon the Sun of a comet (believed to be a dense, hard body), which Buffon suggested was the probable natural cause of the impulsion figuratively attributed to the Almighty in Figure 42.[38]

Yet even merely ornamental illustrations have value to the historian when (as in iconography) they suggest a shared idiom of artistic conventions that were readily recognized by the original readers and interpreted by them in ways that might otherwise escape our notice. Rhetoric is almost never "mere rhetoric," even when it is visual rhetoric. A rhetorical interpretation of Buffon's ornamental illustrations shows how they embodied the needs of the writer and the expectations of his audience at particular times. First, consider that Buffon's cyclic account of the Earth in the "Second discours," the "Histoire & Théorie de la Terre," had nothing to do with the initial cracking open of the original ocean bed as illustrated in Figure 41 (which accompanied its title page). As we have seen, Buffon's Theory was classed with Louis Bourguet's Aristotelians by Élie Bertrand.[39] Even Buffon's defense in the

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[37] Translation slightly emended from Georges Louis Leclerc Comte de Buffon, "Proofs of the Theory of the Earth," in *From Natural History to the History of Nature: Readings from Buffon and His Critics,* trans. and ed. John Lyon and Phillip Sloan (South Bend: Notre Dame University Press, 1981), 153. Cf. Georges Louis Leclerc Comte de Buffon, "Preuves de la Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière, avec la Description du Cabinet du Roi,* 36 vols. (Paris: De l'Imprimerie Royale, 1749), 1: 131–132.

[38] Georges Louis Leclerc Comte de Buffon, "Preuves de la Théorie de la Terre," in *Histoire Naturelle, Générale et Particulière* (Paris: Aux Deux-Ponts, Chez Sanson & Compagnie, 1785), vol. 1, Figure 43 precedes p. 153.

[39] See "Aristotelian Theories of the Earth," beginning on page 188.

"Preuves" of a cometary impact upon the Sun (as quoted above) was couched in the systemic language of revolutions and regular occurrences rather than as an idiosyncratic event. However disingenuous this may have been for Buffon's cosmogenesis in "Preuves," it certainly was consistent with his "Second discours."[40]

TABLE 45. Ornamental Hexameral Illustrations

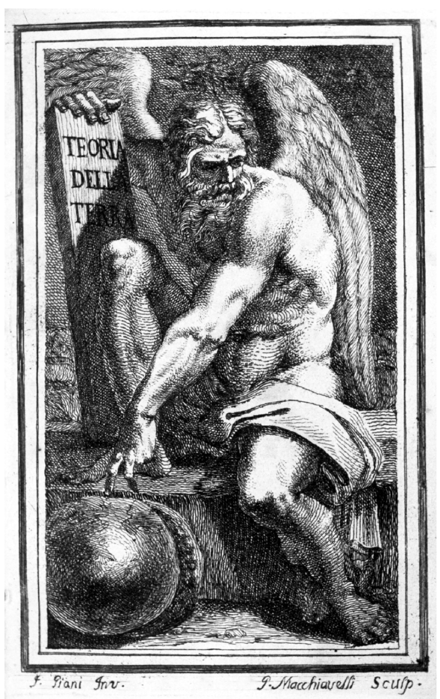

FIGURE 44. Becchetti, frontispiece.[a]

FIGURE 45. Raphael, Third Day of Creation; Sistine Chapel ceiling.

a. Filippo Angelico Becchetti, Teoria Generale della Terra, esposta all'Accademia Volsca di Velletri (Rome: Per Paolo Giunchi, 1782). LH.

However poorly the images may have represented the actual content of his theory, both Figure 41 and Figure 42 accurately anticipated and disavowed the alleged eternalistic tendencies for which Buffon was severely criticized.[41] Artistically, Figure 41 reflects a non-Aristote-

[40] Kenneth L. Taylor's helpful distinction between systemic and idiosyncratic uses of cosmology is discussed in Chapter 2, "On the Boundaries of Cosmology," particularly on page 253. On attempts by Buffon and others to couch idiosyncratic theories as systemic ones see footnote 91 on page 312.

lian tradition: the separation of the dry land and origin of the ocean beds was a central theme in visual representations of the third day of creation, and the event was often supervised by an attending angel (as in Figure 41) if not the Almighty himself (as in Figure 42), who might be depicted in the act of scooping out the ocean basin with a finger (cf. Figure 44 and Figure 45). Buffon's Figure 41 and Figure 42 echo hexameral visual conventions just as his discrimination of six epochs in *Les Époques de la Nature* figuratively recalled the six days.[42] Given the storm of criticism he encountered from Jansenists and other theologians, Buffon's visual and verbal overtures to conventional hexameral interpretation, cosmetic though they were, reflected an accurate assessment of his need to assuage the religious sensibilities and exegetical concerns of his readers.[43] By 1785 (several years after the publication of *Les Époques de la*

[41] In February, 1750, the Jansenist, anti-Jesuit *Nouvelles ecclésiastiques* criticized Buffon's system as tending to eternalism: "Thus we have a world far older than Moses made it out to be. Who shall tell us even when it began? How many centuries were necessary in order that the flux and reflux of the waters should form the mountains which are on the earth? But whereas the sea covered all the earth which is inhabited today, the vast extent which the sea presently occupies will come to be dry and filled with mountains, which must in turn be worn away by rain, until the entire surface of this former continent being levelled, the sea may have taken it and given ours once more to discovery. *Those who make the world eternal, and who see only a continual recurrence of the same events, do they think differently from M. de Buffon*?" John Lyon and Phillip R. Sloan, trans. and eds., *From Natural History to the History of Nature: Readings from Buffon and His Critics* (Notre Dame: University of Notre Dame Press, 1981), 243–244, italics added. Whether justly or not, similar criticisms were made of the Huttonian system.

[42] Cf. Walter Moser, "Buffon: Exégète entre théologie et géologie," *Strumenti Critici* (1987): 17–42.

[43] The Sorbonne's condemnation (1751) of the *Histoire naturelle* is translated in John Lyon and Phillip R. Sloan, eds., *From Natural History to the History of Nature: Readings from Buffon and His Critics* (Notre Dame: University of Notre Dame Press, 1981). The first four of the propositions Buffon was asked to retract pertained to his Theory of the Earth. The Sorbonne may have acted in response to critical reviews in the *Nouvelles ecclésiastiques* the year before. Jesuit reviews in the *Journal de Trévoux* (1749–1750) were more temperate (in contrast to their sharp denunciations of the *Encyclopédie* in 1751), criticizing Buffon's cosmogenesis for several specific apparent contradictions to the hexameral sequence while applauding his refutation of previous systems, affirming his acknowledgement of scriptural authority, and exonerating him from the eternalism of Maillet. Buffon immediately submitted to the Sorbonne and published a retraction in the next volume of the *Histoire naturelle*. The retraction and a selection of critical reviews are translated by Lyon and Sloan. A judicious account of the entire episode is Jacques Roger, *Buffon: A Life in Natural History*, trans. Sarah Lucille Bonnefoi, Cornell History of Science Series, ed. L. Pearce Williams (Ithaca: Cornell University Press, 1997), Chapter 13. Roger comments (p. 186) "The fact that the Jesuits praised the *Natural History* was perhaps reason enough for the Jansenists to attack it," and explains the ensuing dilemma for the Sorbonne (p. 187): "For the College [Sorbonne] not to react was to expose itself to the vicious criticism of the Jansenists. To condemn a book published by the Royal Press, the work of a high-ranking civil servant well-established at the Court, and which was already a commercial success, was to expose itself to ridicule." Buffon's published retraction (p. 189) "served for close to thirty years as a safeguard and protection against all official accusations of irreligion. During these thirty years, Buffon continued publishing these texts without changing a single word." Studies of Buffon's religious inclinations include Jean Piveteau, "La Pensée Religieuse de Buffon," in *Buffon*, ed. Roger Heim (Paris, 1952), 125-132; Jean Stengers, "Buffon et la Sorbonne," *Études sur le XVIIIe Siècle* (1974): 97–127; Geoffrey Bremner, "Buffon and the Casting Out of Fear," *Studies on Voltaire and the Eighteenth Century* 205 (1982): 75–88; and Gurdon Wattles, "Buffon, d'Alembert and Materialist Atheism," *Studies on Voltaire and the Eighteenth Century* 266 (1989): 285–341.

Nature in a supplemental volume of the *Histoire naturelle*) it was possible to be more daring: the supervising angel was reduced to the "spirit of nature," and the representation of the Almighty at the creation of the solar system was omitted in favor of a naturalistic representation (Figure 43).[44]

Thus even ornamental illustrations are of historical value, and although the example of Buffon is but briefly considered here, it raises questions as to what degree at particular times for specific readers visual conventions (not unchanging) may have played more than an ornamental role and functioned as more than mere visual aids. Was it possible for images to play a substantive role in shaping the terms of questioning and debate, influencing ways in which problems were formulated to direct empirical research, or providing criteria by which various possible answers were pursued as promising or assessed as warranted?

[44] Georges Louis Leclerc Comte de Buffon, *Histoire Naturelle, Générale et Particulière* (Paris: Aux Deux-Ponts, Chez Sanson & Compagnie, 1785), vol. 1. Figure 41 has a new caption which dispenses with the angel: "La Genie de la Nature dans la Contemplation de l'Univers." In "Preuves de la Théorie de la Terre" Figure 42 is absent; in its place Figure 43 precedes p. 153. Buffon's *Époques de la Nature* was published in 1778 as the fifth volume of the *Supplement* to the *Histoire Naturelle*; Georges Louis Leclerc Comte de Buffon, "Époques de la Nature," in *Histoire Naturelle, Générale et Particulière, Supplement*, vol. 5 (Paris: De l'Imprimerie Royale, 1778), 1–254. A modern edition is Georges Louis Leclerc Comte de Buffon, *Les Époques de la Nature*, ed. Jacques Roger, Édition critique, with introduction and notes, Mémoires du Muséum National d'Histoire Naturelle, Séries C, no. 10 (Paris: Éditions du Muséum, 1962). Cf. Kenneth L. Taylor, "The *Époques de la Nature* and Geology During Buffon's Later Years," in *Buffon 88: Actes du Colloque International pour le bicentenaire de la mort de Buffon*, ed. Jean Gayon (Paris: Vrin, 1992), 371–385.

§ 4-ii. Discovery and Demonstration through Nontechnical Diagrams

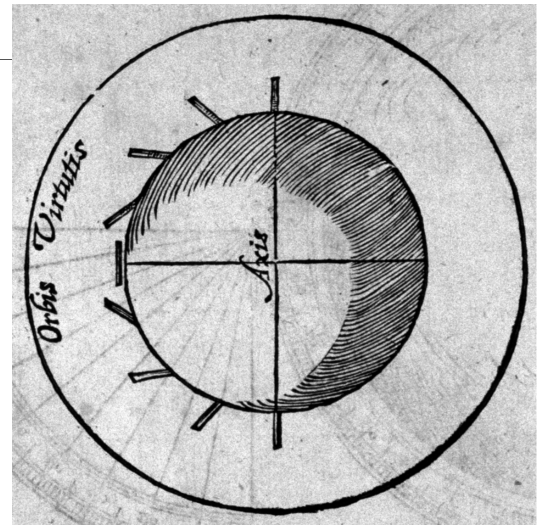

FIGURE 46. Dip or "verticity" of a terrella[45] depicted by William Gilbert, *De magnete,* 1600, Book V, chapter II. Image rotated to make axis vertical. HSCI.

Explanation. "At the equator the bits of iron are directed toward the poles, and lie upon the body of the terrella in the plane of its horizon. The nearer they are placed to the poles the more do they rise from the horizontal by reason of their turning poleward; at the poles they tend straight to the centre."[46]

Without doubt, images and representation lay at the heart of natural knowledge in the seventeenth century. Whether one considers cosmic sections or human anatomy, mapmaking or the natural history of the New World, descriptions of instruments or discoveries made with the telescope and microscope—each of these featured a wealth of prominently deployed images. This is not to say that images could stand on their own, although the wealth of early modern imagery is wonderfully apparent from *Nova Reperta*, a series of twenty-four plates engraved by Jan van der Straet in the 1580s. Stradanus' plates show that in some cases images were published with minimal adorning text, but these are not the focus of this study.[47] In the case of images deployed in the manner of textual traditions, the words and the images reinforce one another and must be "read" together. In addition, if this were not the case, a study

[45] "Terrella" refers to a spherical magnet which served Gilbert as an experimental model of the Earth. For example, in Book V Gilbert discussed how the dip or verticity of a magnetic needle varies with terrestrial latitude. In Book VI Gilbert asserted (p. 313) that "All the experiments that are made on the terrella, to show how magnetic bodies conform themselves to it, may—at least the principal and most striking of them—be shown on the body of the earth." Gilbert explicitly included verticity in this context, although he denied (p. 332) that he had ever observed a terrella to rotate on its axis every twenty-four hours (as Petrus Peregrinus had asserted); William Gilbert, *De magnete,* trans. P. Fleury Mottelay (New York: Dover, 1958).

[46] William Gilbert, *De magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua, plurimis & augmentis, & experimentis demonstrata* (London: Excudebat Petrus Short, 1600), image on p. 193. The caption is from a convenient English edition (originally published 1893); William Gilbert, *De magnete,* trans. P. Fleury Mottelay (New York: Dover, 1958), 285.

[47] The *Nova reperta* plates are republished as Stradanus, *New Discoveries* (Norwalk, CN: Burndy Library, 1953).

of images without related texts runs a greater risk of imposing arbitrary and subjective interpretations of the images. For these reasons the interpretations of images in this study are carefully coordinated with analysis of the accompanying texts. Figure 46 provides an example of the use of images interlaced with textual description; considered together, the figure with its accompanying text is more intelligible than either by itself.[48]

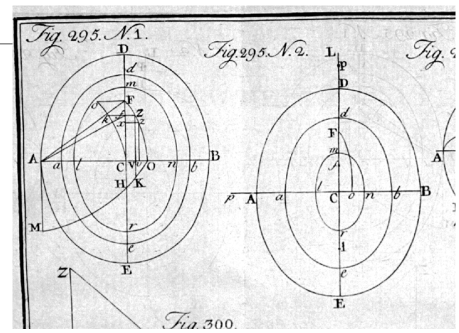

FIGURE 47. Maclaurin, *Fluxions* (1742), Hollow Earth. LH.[49]

Contrast Gilbert's depiction of the terrella—understandable to any reader without prior technical training—with the two diagrams in Figure 47, taken from an eighteenth-century mathematical work. They were used to demonstrate the theoretical possibility, given Newtonian physics, of a hollow Earth according to the magnetic Theory of Edmond Halley. Despite the similar interlacing of diagrams and explanatory text (in this case, the explanatory text consisted of a geometric proof), these abstract global sections reflect the character of a technical tradition in mathematics rather than a text in the Theories of the Earth tradition. Just as Theories of the Earth grade into works of various related technical disciplines, global visions grade into technical representations. In Chapter 6 we will return to magnetic Theories of the Earth, but here the question is how the use of non-technical diagrams such as Gilbert's terrella, or global sections and views in Theories of the Earth, served the demonstrative and didactic needs of textual traditions and thereby may have facilitated the development of technical research programs in new fields or disciplines.[50]

[48] As one historian of visual representation has observed, by the dawn of the seventeenth century "textuality was no longer sufficient; images now carried a weight of demonstration and evidence. Gilbert's map [of the Moon] was itself a type of visual experiment, an attempt to demonstrate through inscription his conclusion that the bright areas of the Moon's surface were water, the dark areas land, and the whole a true territory that might one day belong to England." Montgomery, *The Moon,* 104.

[49] Colin MacLaurin, *A Treatise of Fluxions*, 2 vols. (Edinburgh: Printed by T. W. and T. Ruddimans, 1742).

Consider the continuum between abstract diagrams and naturalistic pictures. On the one hand, Martin J. S. Rudwick has brilliantly analyzed the development of a visual language for geology as practitioners moved away from naturalistic depictions of topography toward more abstract maps and schematized sections. Abstract diagrams, then, may serve technical purposes more satisfactorily than naturalistic pictures.[51] On the other hand, Winkler and Van Helden argue that in the work of Hevelius the visual component became central in communicating astronomical observations, because earlier diagrams of the lunar surface were replaced by fully naturalistic pictures (which alone could be fully accurate), and in this way astronomy became a visual science. In the case of seventeenth-century observational astronomy, then, naturalistic pictures served technical purposes more satisfactorily than abstract diagrams.[52] The cases of astronomy and geology therefore show that technical traditions may rely on either abstract diagrams or naturalistic pictures, or both. Clearly, to describe the role of images in textual or technical traditions we must consider other factors than the degree of abstraction or naturalism.

[50] See "Textual versus Technical Traditions," beginning on page 79. For a discussion of the global sections of Gilbert, Halley, Maclaurin and others, see "Magnetic Theories of the Earth," beginning on page 631.

[51] For the development of a visual language for geology see footnote 5 on page 369.

[52] Mary G. Winkler and Albert Van Helden, "Representing the Heavens: Galileo and Visual Astronomy," *Isis*, 1992, 83: 195–217. Their argument is discussed in the next chapter; cf. "The Natural Face of a Wrecked and Ruined World," beginning on page 486.

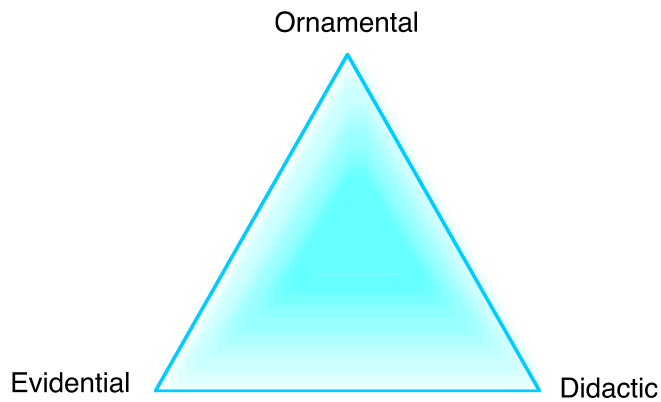

FIGURE 48. Three uses of non-technical visual representations.

Provisionally, we may locate any visual representation in a non-technical tradition somewhere within the three vertices on the triangular map of Figure 48. If the map were drawn in three-dimensions, any point within the triangle might be marked either above or below the page to indicate the degree to which an illustration is abstract or naturalistic. For example, in the previous section we considered ornamental aspects of visual representations, and ornamental images may range from abstract designs to naturalistic pictures. The latter frequently contain allegorical and symbolic elements serving as relational shorthand for those initiated in ornamental conventions. Examples include Buffon's global illustrations (cf. Table 44 in the previous section), and the emblematic scheme of Robert Fludd considered later in this chapter (Figure 75 on page 425). Rudwick's survey of depictions of prehuman landscapes offers further examples of ornamental naturalism.[53]

A second use of illustrations is the evidential, where images represent the contingent fact that something happens to be the case. Evidential portrayals report unexpected discoveries, singular events, specific places, particular specimens, or an isolated aspect of some object which might have been otherwise. Examples of evidential abstraction include the technical diagrams of the visual language of geology analyzed by Rudwick. Hamilton's depictions of the eruptions of Etna and Vesuvius are examples of evidential naturalism.[54] Additional examples

53 Cf. Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992).

54 See "Hamilton and Literary Genres of Theories of the Earth," beginning on page 159.

include the prehuman landscapes surveyed by Rudwick (which were also ornamental), and Galileo's depictions of the roughness of the Moon evidencing its cratery surface. Naturalistic representations, particularly in ornamental and evidential uses, have been cited as fundamental to the seventeenth-century Scientific Revolution by Erwin Panofsky and Samuel Y. Edgerton, among others. On this view the development by Renaissance artists and engineers of practices of linear perspective and naturalistic representation correlate with the "geometrization of nature," or the breakdown of the hierarchical cosmos and the substitution of infinite Euclidean space.[55]

Finally there is the didactic use of illustrations, which applies to many of the global sections and views in Theories of the Earth. Didactic refers to the role of images in conveying ideas or demonstrating how something might be the case, as in depictions of actual or possible mechanical models. An example of didactic naturalism might include Galileo's depictions of the cratery surface of the Moon (which were also evidential), because didactic images (naturalistic or abstract) assist both writers and readers in clarifying their conceptions. In the context of discovery, self-referential didactic illustrations that are neither overly abstract nor overly naturalistic may help one to formulate initial conceptualizations, for visual perception may precede the ability adequately to express an idea using words alone.[56] For this and other reasons the Panofsky-Edgerton interpretation has been vigorously disputed by Michael

[55] See especially Samuel Y. Edgerton, Jr., "The Renaissance Development of the Scientific Illustration," in *Science and the Arts in the Renaissance*, ed. John W. Shirley and F. David Hoeniger (Washington, D.C.: Folger Shakespeare Library; London, Toronto: Associated University Presses, 1985), 168–197. "Geometrization of nature" is Koyré's phrase; Alexandre Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins University Press, 1957). Cf. Erwin Panofsky, *The Life and Art of Albrecht Dürer*, 4th ed. (Princeton: Princeton University Press, 1955); Samuel Y. Edgerton, Jr., *The Renaissance Rediscovery of Linear Perspective* (New York: Basic Books, 1975), and Samuel Y. Edgerton, Jr., *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution* (Ithaca: Cornell University Press, 1991). Winkler and Van Helden's interpretation of Hevelius' astronomy is consistent with (and seems to have been influenced by) Edgerton's thesis (footnote 52). Edgerton also emphasizes the role of machine illustrations, which in some cases approaches the didactic use of images noted below. My specification of a three-fold range of uses of visual representations in addition to the abstract-naturalistic polarity is intended in part as an improvement of the terms of debate established by Edgerton.

Mahoney, among other historians.[57] In a particularly instructive study investigating the didactic use of images, Bert Hall argues against the Edgerton thesis:

> it seems rash to conclude that scientific and technical illustrations were significantly aided by the development of naturalism or their newly acquired ability to be printed in as many 'exactly repeatable' examples as the printer saw fit to produce. Not only do we sense that naturalistic drawings may be approximately as theory-laden (or as theory-free) as 'diagrams,' there is simply no warrant for the assumption that artistic naturalism is accompanied by a deep commitment to what we may as well call 'empiricism' on the part of scientific authors.[58]

Didactic abstraction is most obvious, perhaps, in technical diagrams such as Maclaurin's geometrical figures, but the didactic use is by no means limited to technical contexts. The cosmogonic sequences of Robert Fludd, Descartes, Burnet, and others analyzed in the next

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[56] Cf. Scott Montgomery's interpretation of Gilbert's map of the Moon in footnote 48. Another example of a clearly didactic use of early lunar telescopic depictions is discussed by Montgomery, which shows how difficult it was for Galileo's contemporaries to perceive the rough, cratery aspect of the lunar surface: "[Thomas] Harriot sent his first telescope to [William] Lower in late 1609 or early 1610, advising him to pursue his own observations. In a letter dated February 6, 1610, Lower wrote back to thank Harriot for 'the perspective cylinder': 'According as you wished I have observed the Moone in all his changes... [Near] the brimme of the gibbous part towards the upper corner appeare luminous parts like starres, much brighter than the rest, and the whole brimme along lookes like unto the description of coasts, in the dutch bookes of voyages. In the full she appeares like a tarte that my cooke made me the last weeke. Here a vaine of bright stuff, and there of darke, and so confusedlie al over.' Lower is groping here, seriously and playfully, to find an apt description. Words fail him; Harriot's own drawing (which also had been sent) provides little help. Stars, coasts, a tart, a confusion of light and dark: Lower is trying to make sense of what he sees and can only produce a surplus of images, a narrative 'confusedlie al over.'" Montgomery, *The Moon*, 111. On similar grounds Ariew notes that the existence of mountains on the Moon was widely regarded in scholastic circles as a conclusion or an inference, instead of a direct observation; Roger Ariew, *Descartes and the Last Scholastics* (Ithaca: Cornell University Press, 1999), 101.

[57] Michael S. Mahoney, "Diagrams and Dynamics: Mathematical Perspectives on Edgerton's Thesis," in *Science and the Arts in the Renaissance,* ed. John W. Shirley and F. David Hoeniger (Washington, D.C.: Folger Shakespeare Library; London, Toronto: Associated University Presses, 1985), 198–220. Mahoney's arguments for a progression from more concrete to more abstract modes of illustration apply primarily to technical (particularly geometrical) traditions in early modern mathematical physics, rather than to the use of didactic images in ongoing textual traditions considered here. Moreover, participants in the Mahoney-Edgerton debate usually share a common conception of the Scientific Revolution (e.g., Koyré's) which frames their selection of the important texts to be discussed, excluding from consideration for all practical purposes alternative traditions such as the chymical philosophies or Theories of the Earth (cf. Chapter 2).

[58] Bert S. Hall, "The Didactic and the Elegant: Some Thoughts on Scientific and Technological Illustration in the Middle Ages and Renaissance," in *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, ed. Brian S. Baigrie, Toronto Studies in Philosophy (Toronto: University of Toronto Press, 1996), 20; hereafter Hall, "The Didactic and the Elegant." Hall's conception of "Elegant" refers to naturalistic representations as opposed to abstract diagrams, and therefore may apply to both ornamental and evidential uses as described here. With respect to the claim raised in the first sentences of this quote, Adrian Johns demonstrates that it is mistaken to assume that print culture provided "exactly repeatable" books, a fact that is as relevant to images as to texts. No demonstration of this point is better than Johns' reproduction on two facing pages of Galileo's depictions of the lunar surface as published in four different editions of the *Sidereus nuncius*; Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago: Chicago University Press, 1998), 22–23.

chapter are excellent examples of didactic illustrations, neither ornamental nor evidential in their primary role, and often not entirely abstract. To them and other didactic images the words of Gaston Bachelard aptly apply: "To make representation geometric, in other words to make drawings of phenomena and to place in an ordered series the decisive events of an experience—such is the first task in which the scientific spirit affirms itself."[59]

Descartes' use of visual images is analyzed in detail in the next chapter, but from the start we may note that in these terms Descartes' illustrations were almost always didactic, and neither overly naturalistic nor overly abstract. Descartes commended visual representations in a mechanical style—such as his depiction of vortices in Figure 83 on page 453—as more helpful in conveying his cosmology than verbal descriptions: "For these things depend on mathematics and mechanics, and can be demonstrated better in a visual demonstration than they can in a verbal explanation."[60] Thus Descartes provided his diagrams not as visual aids but as a means of thinking. Of course, John Keill criticized Descartes for talking about the need for geometry without doing any, and no one would mistake Descartes' diagrams for technical geometrical proofs like Maclaurin's.[61] But this may be a strength and virtue for didactic (as opposed to technical or evidential) images. Descartes assured Burman that none of his diagrams were inaccessible to non-expert readers. As Brian Baigrie explains, Descartes argued

[59] Gaston Bachelard, *La Formation de l'Esprit Scientifique,* 2d ed., (Paris, 1983), 5. Quoted and translated in Montgomery, 222. Bachelard was writing of illustrations which hover between the concrete and the abstract, seeking to reconcile laws and facts, although he might be aghast to learn that his comments have been applied to cosmogonic sections.

[60] The sentence occurs in section 67 of Descartes' *Conversation with Burman*: "It is scarcely possible to understand this figure [regarding the motions of the vortices] without the help of eight or so little balls to demonstrate the movement. The author [i.e., Descartes himself], despite the fact that he has accustomed his mind to imagining, was scarcely able to conceive of it without the balls. So others will find it much more difficult. For these things depend on mathematics and mechanics, and can be demonstrated better in a visual demonstration than they can in a verbal explanation." René Descartes, *Descartes' Conversation with Burman*, trans. John Cottingham, with Introduction and Notes (Oxford: Clarendon Press, 1976), 41; cf. Adams and Tannery 5:172. Edgerton's studies of mechanical illustrations (footnote 55) remain useful for considering early modern didactic illustrations, if the focus of discussion can be shifted away from the abstract vs. naturalistic polarity and from the preoccupation with the origin of the Scientific Revolution.

[61] For Keill's criticism of Descartes' diagrams as being something other than geometrical see page 152.

that even for non-technical uses, line-drawings and mechanical diagrams (often geometrical representations of mechanical models) are more useful than naturalistic pictures.[62]

A century after Descartes, Thomas Wright employed images in a manner not far different from the mechanical models of Descartes. Wright explained why his *Original Theory of the Universe* (1750) was so profusely illustrated, advancing what amounts to a manifesto of the virtues of nontechnical didactic images in a textual tradition:

> I know you are an Enemy to all Sorts of Schemes where they are not absolutely necessary, and may possibly be avoided; and for that Reason I have purposely omitted many geometrical Figures, and other Representations in this Work, which might have been inserted and in some Places, especially here I might have introduced Diagrams, perhaps more explicit than Words; but as you have frequently observed, they are only of Use to the few Learned, and contribute more to the taking away the little Ideas and Knowledge the more ignorant Many may be endued with, by a prejudicial Impression of imperfect Images, rather than the adding any new Light to their Understanding, I have purposely avoided, as much as possible, both here and every where, all such complex Diagrams as might be in Danger of betraying any the least such conscious Diffidence in you, arising from the Want of a proper *Precognita* in the Sciences.... I shall therefore content myself with referring you to a few orbicular Figures, concave and convex, as may best suggest to your Fancy the simplest Way, a just Idea of the Hypothesis I have fram'd, and naturally enough I hope, render my Theory so intelligible, as to help you sufficiently to conceive the Solution aimed at...[63]

Wright eschewed technical geometrical diagrams in order to make his work accessible to non-expert readers. In Table 46 compare three of Wright's cosmic views (Figure 50, Figure 52, Figure 54) paired with three matching cosmic sections (Figure 51, Figure 53, Figure 55). Wright offered them in the belief that, in contrast to abstract and "imperfect Images," non-technical pictures would help a general audience grasp his meaning, to conceive "a perfect Idea of what I mean by such a Theory." Wright's didactic use of cosmic sections and views mirrors the deployment of global sections and views in many Theories of the Earth.

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62 Brian S. Baigrie, "Descartes' Scientific Illustrations and 'la grande mécanique de la nature'," in *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science*, ed. Brian S. Baigrie, Toronto Studies in Philosophy (Toronto: University of Toronto Press, 1996), 86–134; cf. footnote 350 on page 602.

63 Wright, *Original Theory,* 58.

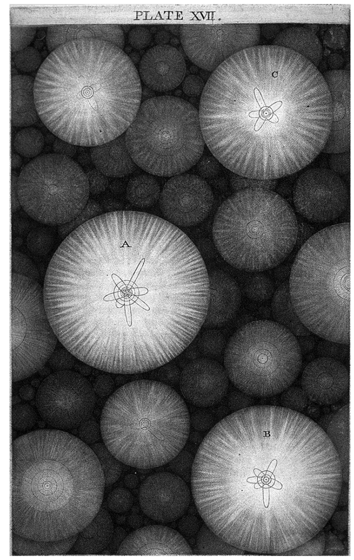
Many of the earliest Theories of the Earth included nontechnical illustrations not merely to adorn the text in an ornamental way, but as figures so intimately embedded in the narrative that the verbal explanations would have been unintelligible without them. Of course, the use of illustrations was dependent on the lively print culture that followed the explosion of publishing. However, there is more involved in the use of such images than the ability to accurately reproduce naturalistic pictures.[64] When they are understood as didactic illustrations they share some of the characteristics of textual traditions such as accessibility to non-experts and ongoing appropriation or contested continuity, and may be analyzed as (or in parallel to) other textual traditions.[65] Any account of seventeenth-century natural knowledge that omits analysis of didactic, evidential, and even ornamental visual representation is insufficient. To understand the tradition of Theories of the Earth as a whole, the deployment of visual elements in Theories of the Earth cannot be ignored.

[64] The classic study of print culture is Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early Modern Europe,* 2 vols. (Cambridge: Cambridge University Press, 1979); see also the essay reviews by Robert S. Westman, "On Communication and Cultural Change," *Isis* 71 (1980): 474–477, and Anthony T. Grafton, "The Importance of Being Printed," *Journal of Interdisciplinary History* 11 (1980): 265–286. Recent work by Adrian Johns undermines many characterizations of print culture (cf. footnote 58 on page 391): "The disconnected air exhibited by Eisenstein's account is not accidental. In her work, printing itself stands outside history.... Its 'culture' is correspondingly placeless and timeless. It is deemed to exist inasmuch as printed texts possess some key characteristic, fixity being the best candidate, and carry it with them as they are transported from place to place." Adrian Johns, *The Nature of the Book*, 19. The present description of Theories of the Earth as a contested textual tradition avoids attributing the character of fixity to a reified genre; cf. the discussion of texts as boundary objects in "Textual versus Technical Traditions," beginning on page 79.

[65] This point is asserted above; cf. footnote 143 on page 74.

TABLE 46. Thomas Wright, Original Theory of the Universe, 1750. HSCI.

FIGURE 49. Wright, Plate XVII, p. 51. HSCI



Explanation. Plate XVII "Represents a kind of perspective View of the visible Creation, wherein A represents the System of our Sun, B, that supposed round Syrius, and C, the Region about Rigel. The rest is a promiscuous Disposition of all the Variety of other Systems within our finite Vision, as they are supposed to be posited behind one another, in the infinite Space, and round every visible Star."

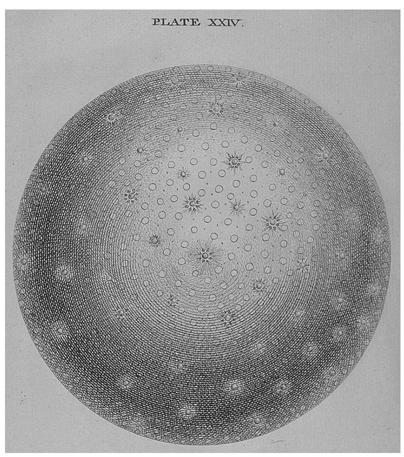


FIGURE 50. Wright, Plate XXIV. HSCI

Explanation. "Is a Representation of the Convexity, if I may call it so, of the intire Creation, as a universal Coalition of all the Stars consphered round one general Center, and as governed by one and the same Law.

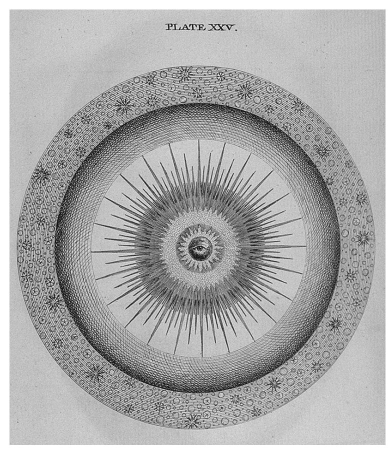


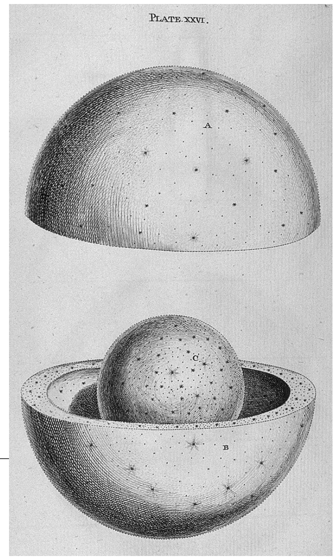
FIGURE 51. Wright, Plate XXV. HSCI

Explanation. "Is a centeral [sic] Section of the same, with the Eye of Providence seated in the Center, as in the virtual Agent of Creation."

Description. "...what less than an Infinity can circumscribe them, less than an Eternity comprehend them, or less than Omnipotence produce and support them, and where can our Wonder cease?" Wright, *Original Theory,* 42–43.

TABLE 46. Thomas Wright, Original Theory of the Universe, 1750. HSCI.

FIGURE 52. Wright, Plate XXVI. HSCI



Explanation. "Represents a Creation of a double Construction, where a superior Order of Bodies C, may be imagined to be circumscribed by the former one A, as possessing a more eminent Seat, and nearer the supream Presence, and consequently of a more perfect Nature."

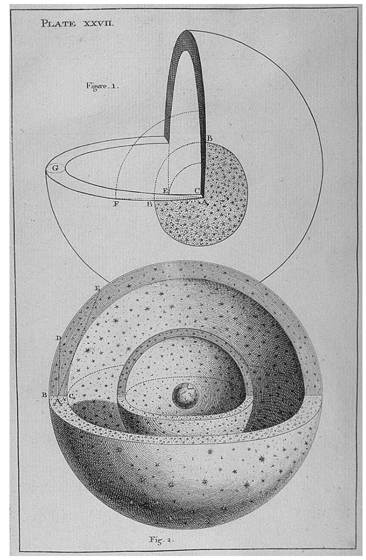


FIGURE 53. Wright, Plate XXVII. HSCI

Explanation. "Represents such a Section, and Segments of the same, as I hope will give you a perfect Idea of what I mean by such a Theory."

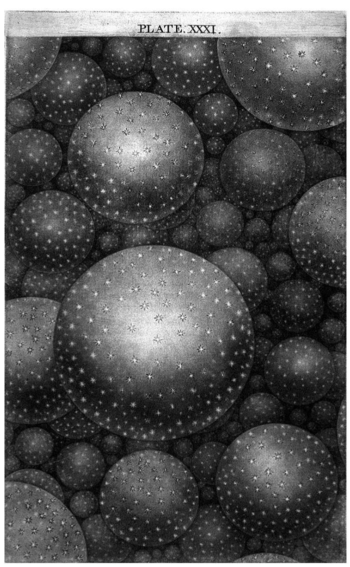


FIGURE 54. Wright, Plate XXXI. HSCI

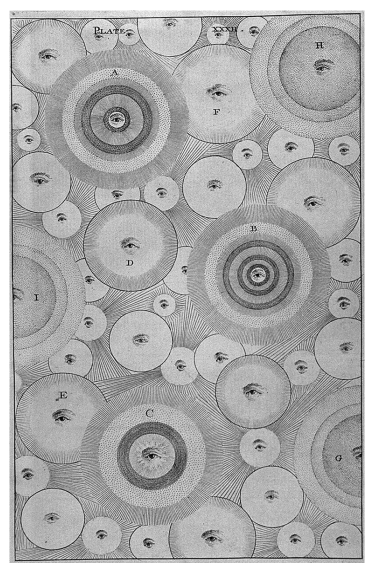


FIGURE 55. Wright, Plate XXXII. HSCI

"That this in all Probability may be the real Case, is in some Degree made evident by the many cloudy Spots, just perceivable by us, as far without our starry Regions, in which tho' visibly luminous Spaces, no one Star or particular constituent Body can possibly be distinguish'd; those in all likelyhood may be external Creation, bordering upon the known one, too remote for even our Telescopes to reach." Wright, 83–84.

§ 5. Self-Portrait of the Tradition

To examine some of the visual depictions of the globe by which Theories of the Earth were conveyed provides an illuminating overview of the tradition. Some of the subjects and ideas of importance to Theorists of the Earth were not embedded in visual representations, of course.[66] Yet an impression of Theories of the Earth obtained by sampling their visual illustrations will be more representative, it is hoped, than if one surveyed them on the basis of a single theme suggested by criteria arising from outside the historical tradition itself. Such externally-imposed organizing themes include those which appear "internal" and technical from the point of view of a later geologist (e.g., a Theorist's concepts, practices, or attitudes regarding the age of the Earth, earthquakes, volcanos, mountains, the Earth's core, geological mapping), those which seem to be conceptually "external" to the technical aspects (e.g., aesthetics of nature, epistemology, views of providence), or those which are social and contextual (e.g., audience, ideology, rhetoric).[67] Each of these interpretive themes is important and significant for our understanding of what Theories of the Earth were like, but none is capable by itself of conveying the historical character and scope of the tradition. So while visual elements constitute an important aspect of Theories of the Earth which merits special attention in its own right, their study also promises to leave intact the holistic interrelationships of other

[66] Similarly, not even the topics which do surface in the discussion of visual elements will receive an exhaustive treatment. As even Descartes admitted, "all things cannot be explained here." *Principia Philosophiae* Part IV, question 37; *Principles of Philosophy*, trans. R. P. Miller and V. R. Miller, Synthese Historical Library, 24 (Dordrecht: D. Reidel, 1983), 199. However, I do attempt to systematically "read" the illustrations of the two major Theorists of the seventeenth century, René Descartes and Thomas Burnet.

[67] For excellent surveys of the technical contents of Theories of the Earth see Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries* (New York: Columbia University Press, 1934, reprinted New York: Octagon Books, 1968); Gordon L. Herries Davies, *The Earth in Decay: A History of British Geomorphology, 1578-1878* (New York: American Elsevier Publishing Company, 1969); and François Ellenberger, *La Grande Éclosion et ses Prémices, 1660–1810,* vol. 2 of *Histoire de la Geologie,* 2 vols., Petite Collection d'Histoire des Sciences (Paris: Technique et Documentation—Lavoisier, 1994). For helpful external and contextual studies, see Roy S. Porter, *The Making of Geology: Earth Science in Britain, 1660–1815* (Cambridge: Cambridge University Press, 1977); Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca: Cornell University Press, 1959); and Michael Macklem, *The Anatomy of the World: Relations between Natural and Moral Law from Donne to Pope* (Minneapolis: University of Minnesota Press, 1958). However, any internal-external distinction is arbitrary and problematic, and ultimately untenable for the historiography of Theories of the Earth.

themes and to present us with a natural portrait of the tradition drawn from the works themselves.

The remainder of this chapter introduces general themes by means of a quick survey of cosmic sections and biblical illustration up to the seventeenth century. In Chapter 5, "Textual Assimilation: The Sacred Theory of Burnet," visual representations from the two most significant seventeenth-century Theories of the Earth are examined in detail; these works are those of René Descartes (1596–1650) and Thomas Burnet (ca. 1635–1715). A close "reading" of Burnet's frontispiece and accompanying illustrations discloses a systematic appropriation and striking transformation of the cosmogonic illustrations of Descartes, just as Descartes had appropriated and transformed visual representations from his own day. In Chapter 6, "Technical Naturalization: Portraits of a Dynamic Tradition," brief glances are directed toward illustrations from a number of other Theories, including Edmond Halley (1656–1742), John Woodward (1665–1728), John Strachey (1671–1743), and John Whitehurst (1713–1788).[68]

Considered together their visual elements disclose much of the specific historical character of Theories of the Earth, and at the same time display the tradition's considerable variety. Earth Theorists exhibited little consensus, even on points adopted tacitly by some writers without explicit defense, and still less on the controversial matter of what properly should characterize a Theory of the Earth. Yet each Theorist, by entering into print with negative critiques or positive contentions, participated in the public dialogue that constituted the tradition and shaped its ongoing redefinition. The continuities and discontinuities of visual representations reflect the origin of an historically-situated discourse marked by its public and heterogenous character. Thus Theories of the Earth were a contested textual tradition, one which served as an arena for vigorous general debate in the public sphere concerning the relation between natural order and historical contingency in the constitution of the Earth.

[68] The sheer number of global sections and views published in various Theories of the Earth has made it impossible to consider every example in this study.

§ 6. Precedents: Cosmic Sections and Hexameral Illustration

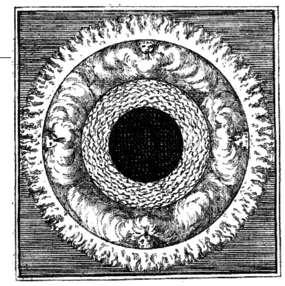


FIGURE 56. Meteorological section.

Cosmic sections provided one set of precedents for global sections and views. The sublunar regions could be extracted from the middle of a cosmic section to stand on their own as a meteorological section. Figure 56, showing concentric layers of earth, water, air and fire, is taken from the title page of a work by Thomas Burnet published in the 18th century.[69]

FIGURE 57. Peter Apian, *Cosmographia* (1548). LH.

Caption. Figura de la diuision de las Spheras.

The Ptolemaic universe was depicted in Peter Apian's *Cosmographia* (Figure 57; 1548).[70] Observe the concentric heavenly spheres from the outermost "Empyrean Heaven, the Habitation of God and all the Elect," down through the sphere of fixed stars and spheres of the planets to the

[69] Thomas Burnet, *Doctrina Antiqua de Rerum Originibus: Or, An Inquiry into the Doctrine of the Philosophers of all Nations, Concerning the Original of the World,* made English from the Latin Original by Mr. Mead and Mr. Foxton (London: Printed for E. Curll, at Pope's Head, in Rose-Street, Covent-Garden, 1736). The significance of the meteorological tradition for Theories of the Earth is discussed in "Case 1: The Meteorological Tradition," beginning on page 222.

[70] Peter Apian, *Cosmographia*, 1548. An identical cosmic section appears in all editions except the first (1535), where a much-reduced cameo depiction is found in its place.

Earth at rest in the center (Table 47).[71] Apian's cosmic section includes beneath the Moon the meteorological regions of fire and air like Figure 56, but in contrast to the rest of the diagram, the Earth is depicted not as a section, but as a surface view showing both dry land and sea.

Many cosmic sections portrayed the Earth not as a section but as a global view seen from space. Imaginative space travel began with the earliest myths. One ancient Greek global view, a verbal rather than pictorial description of the Earth from space, occurs in a passage from Plato's *Phaedo* already considered: "Well, my dear boy, said Socrates, the real earth, viewed from above, is supposed to look like one of these balls made of twelve pieces of skin, variegated and marked out in different colors...."[72] In *Scipio's Dream* Cicero made his readers imagine looking down from the heavens so that "From here the earth appeared so small that I was ashamed of our empire which is, so to speak, but a point on its surface."[73] Such verbal and artistic conventions convey something of the sense in which both the Earth and the Moon were regarded equally as globular *bodies* even before the Earth became a planet and the Moon became a satellite.[74] With Copernicus and certain geocentric cosmologies, the only

71 For a concise tour of the medieval cosmos see C. S. Lewis, *The Discarded Image: An Introduction to Medieval and Renaissance Literature* (Cambridge: Cambridge University Press, 1964). A comprehensive, magisterial survey is Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994).

72 Plato, *Phaedo,* 110b; trans. Edith Hamilton and Huntington Cairns, *The Collected Dialogues of Plato, Including the Letters*, Bollingen Series LXXI (Princeton: Princeton University Press, 1961), 91. See "Platonic Theories of the Earth," beginning on page 175. See related discussion of Plutarch on page 176. Cf. James S. Romm, *The Edges of the Earth in Ancient Thought: Geography, Exploration, and Fiction* (Princeton: Princeton University Press, 1992), 127–128: "Socrates himself becomes that winged being, describing a remarkable vision of the earth 'as one would see it from above' (110b): a brightly colored spherical object adorned with gold, silver, and jewels. In this transcendent description Plato follows a tradition we have looked at above in connection with the Hesiodic *Periodos Ges*, and which would go on to become hugely popular.... Only by flight—whether the actual, airborne journey of the Boreades or the mental and imaginative ascent of the dying Socrates—could one break through the barriers of perception and attain a glimpse of worlds beyond the *oikoumene*. And the panorama thereby achieved was often strikingly beautiful and mysterious, a visible revelation of ultimate truth."

73 Cicero, *Somnium Scipionis,* III.7; translation from Macrobius, *Commentary on the Dream of Scipio,* trans. and ed. William H. Stahl (New York: Columbia University Press, 1952), 72. A striking medieval cosmic section illustrating the *Dream of Scipio* held by the Bodleian Library, Oxford, is reproduced in Peter Whitfield, *Landmarks in Western Science: From Prehistory to the Atomic Age* (New York: Routledge, 1999), as a color plate facing page 49. The wonderful illustrations in this survey text—including many cosmic sections—are by far its best feature; hereafter "Whitfield, *Landmarks*."

74 See "Were theories of the Earth Inconceivable in Pre-Copernican Cosmologies?," beginning on page 228.

necessary change was to make the Earth rotate. Writers such as Francis Godwin, Bishop of Hereford (1562–1633) simply added to these imaginary scenes the visualization of a moving Earth:

> Whereas the Earth according to her naturall motion (for that such a motion she hath, I am now constrained to joyne in opinion with Copernicus) turneth round upon her own Axe every 24. howers from the West unto the East: I should at the first see in the middle of the body of this new starre a spot like unto a Peare that had a morsell bitten out upon the one side of him; after certaine howers, I should see that spot slide away to the East side. This no doubt was the main of Affrike. Then should I perceive a great shining brightnesse to occupy that roome, during the like time (which was undoubtedly none other than the great Atlantick Ocean). After that succeeded a spot almost of an Oval form, even just as we see America to have in our Mapps. Then another vast cleernesse representing the West Ocean; and lastly a medly of spots, like the Countries of the East Indies.[75]

Thus the basis for the thought-experiment we have already encountered in Suess and Wegener was already ancient when in the seventeenth century it was appropriated to convey changes in cosmology.

Cosmic sections appeared with many variations, and expressed social and religious visions of life in the universe which underlay cosmological beliefs. For example, political themes are superbly manifest in three cosmic sections reproduced by I. B. Cohen.[76] The politicization of early seventeenth-century global views has been explored by Scott Montgomery for the case of the Moon.[77] As Apian's section suggests, the locations of God, supercelestial waters, the phys-

[75] Francis Godwin, *The "Man in the Moon" (1638) and "Nuncius inanimatus" (1635),* ed. Grant McColley, Smith College Studies in Modern Languages, no. 19 (Northampton, Mass, 1937), 22 [pp. 56–58 in the 1638 edition]. Kepler wrote of a similar vision in the *Somnium,* cf. footnote 122 on page 490.

[76] I. Bernard Cohen, *Revolution in Science* (Cambridge: The Belknap Press of Harvard University Press, 1985). First, the "Sphaera Civitas" cosmic section from John Case, *Sphaera Civitatis* (Oxford, 1588), depicts Queen Elisabeth astride a section of the Ptolemaic cosmos, 61. The region of the Earth is labelled "Ivstitia Immobilis"; the sphere of fixed stars represents the Star Chamber, Lords, and Counsellors; and the outermost sphere asserts that Elizabeth rules by the will of God. The spheres of the planets are associated with civic virtues such as *religio* (Sun), *clementia* (Venus), and *fortitudo* (Mars). Second, a striking depiction of Copernican cosmology combined with Cartesian vortices in the service of royal power is a cosmic section entitled "Le Systéme du Monde au moment de la Naissance de Louis le Grand," 62. Third, Cohen's interesting frontispiece, "Sistême Astronomique de la Révolution Françoise," dates from the early period of the French Revolution. It depicts "La Nation, La Loi, Le Roi" in the position of the Sun, radiating beneficent influences upon the concentric spheres surrounding it such as the "Atmosphère de la Constitution."

ical body of Christ, blessed saints, and sinners in hell are just a few of the theological topics often embedded in cosmic sections (Table 47).[78]

TABLE 47. Three Regions of Apian's cosmic section

Region	Name	Explanation
I	Empireum	•"Empyrean heaven, the habitation of God and of all the Elect."
II Heavens Includes numbered spheres from 10 down to 1	10. Primum Mobile	•Outermost celestial sphere, moved by God the Prime Mover. •Divided into regions of the zodiac; accounts for trepidation of the equinoxes.
	9. Crystallinum	•Supercelestial waters (ice = crystal = transparent solid) above the firmament. •Divided into regions of the zodiac; accounts for precession of the equinoxes. The two ⊕ symbols represent the equinoxes, where the zodiac intersects the celestial equator.
	8. Firmamentum	•Sphere of fixed stars and constellations. •Divided into regions of the zodiac; accounts for diurnal motion.
	7-1. Coelum	•Spheres for each of the planets from Saturn down to the Moon (including the Sun).
III	Sublunar or meteorological region	•Meteorological (not heavenly) spheres of fire and air surround the terreaqueous globe of a central Earth. •Hell is not shown within the Earth.

As one example of theological involvement with cosmology, consider that medieval and Renaissance discussions about the outer sphere, the empyrean, argued such issues as when it was created, whether it was spatial and temporal or somehow beyond space and time, and

---

77 Montgomery suggests that the selenography of Michael Florent Van Langren (ca. 1607–1675) amounted to a plea for the preservation of a Catholic Europe; cf. "Van Langren: The First Textual Map and a Catholic Moon," Montgomery, *The Moon,* 157–168. Montgomery contrasts Van Langren's strategy with the lunar maps published, after Hevelius, in the *Almagestum novum* (Bononiæ: 1651) of Giambattista Riccioli, who more generously included Protestant and Arabic names yet situated them in politically-relevant places. For example, the *Oceanus Procellarum* (Sea of Storms) contains the crater of *Copernicus* near its central shore; farther out, the crater of Keplerus lies within the *Insula Ventorum* (volcanic island); and the crater *Galileus* lies near the farthest shore. Riccioli's selenography is discussed in Montgomery, chapter 12.

78 Hexameral themes in early modern cosmology are merely touched upon in this chapter; some additional examples and general themes are summarized in the Appendix. For more extensive studies see William H. Donahue, *The Dissolution of the Heavenly Spheres, 1595–1650* (New York: Arno Press, 1981), Chapter 6; and Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994), especially Chapter 5.

who besides the elect might dwell there. Many believed it was created on the first day of the creation week to provide a place for the angels, who otherwise seemed to be left out of Genesis 1. Reformed theology located the glorified body of Christ here along with the blessed spirits of the saints. However, the place of Christ's physical body was much disputed by Lutherans who held to a physical interpretation of Christ's real presence which suggested Christ's body was ubiquitous, i.e., present in some physical way everywhere throughout the universe.[79] Protracted and intense debates between Lutherans and the Reformed at the end of the sixteenth century focused on the real presence and the ubiquity of Christ.[80] In these debates traditional cosmology was deployed against the Lutherans as Christ's ascension to the empyrean provided a plausible location for the physical body of Christ from which he might extend his spiritual presence throughout the cosmos. On the other hand, where would the body of Christ be located in a Copernican universe?[81] Peter Martyr Vermigli, a second-generation Reformer important both on the continent and in England, wrote a representative treatise on the Two Natures of Christ in dialogue format, where Orothetes ("boundary setter") speaks for the Reformed (himself), and Pantachus ("everywhere") for the Lutheran view (modelled after Johannes Brenz, a Lutheran theologian whose arguments on real presence Martyr was rebutting). To serve his theological ends, Orothetes claims that he is asserting nothing new and copiously quotes patristic and scholastic sources on the empyrean heaven, the creation of angels, the work of the first day, and scriptural references to heaven. Pantachus responds:

79 Not all Lutherans held to the ubiquity of Christ's body—even Martin Chemnitz held that Christ is physically present only where he chooses to be, not everywhere. Initially "ubiquity" was a derogatory term invented and applied to the Lutherans by Reformed controversialists who wanted to draw the attention of Lutherans to what the Reformed perceived as unpalatable logical consequences of the Lutheran position—an attempted *reductio ad absurdum*. For recent scholarship on Lutheranism see footnote 90 on page 411.

80 Discussion of the two natures of Christ was often set in the context of disputes between Lutherans and the Reformed over the Eucharist. According to Donnelly, two hundred treatises were published during the sixteenth century; Peter Martyr Vermigli, *Dialogue on the Two Natures of Christ*, trans. John Patrick Donnelly, ed. Joseph C. McLelland, The Peter Martyr Library, ed. John Patrick Donnelly, S.J., and Joseph C. McClelland, no. 2; Sixteenth Century Essays & Studies, no. 30 (Kirksville, Missouri: Thomas Jefferson University Press and Sixteenth Century Journal Publishers, 1995), xiv.

81 Figure 70 on page 413 shows how one early Copernican successfully resolved this problem. The Copernican system was still hierarchical, as was Digges' interpretation of it, but the problem would seem even more acute for non-hierarchical cosmologies like those of Nicolas of Cusa or Descartes.

> Pant.: I see well enough how you've set things up for your people, that beyond the firmament and visible heavens joyous mansions have been prepared; ascending beyond all the heavens, Christ came there; eventually the bodies of the saints will be received there, when they have been raised from the dead on the last day.
>
> Oro.: That's precisely what we believe and teach. We don't allow somebody to push down our throats a heaven of Christ and the saints that is everywhere, not really above and sublime, but having a place throughout all the parts of this lower world, such as you people prattle about.[82]

Recent scholarship has shown that Lutherans were more open to non-traditional cosmologies, and any examination of the Reformed should take account of ways in which this controversy shaped their receptivity, resistance, or adaptation to new cosmologies.[83] It should not be sur-

[82] Peter Martyr Vermigli, *Dialogue on the Two Natures of Christ,* trans. John Patrick Donnelly, ed. Joseph C. McLelland, The Peter Martyr Library, ed. John Patrick Donnelly, S.J., and Joseph C. McClelland, no. 2; Sixteenth Century Essays & Studies, no. 30, (Kirksville, Missouri: Thomas Jefferson University Press and Sixteenth Century Journal Publishers, 1995), 125. In this polemical theological dialogue, the Reformed spokesman Orothetes explained (p. 113): "But all the faithful confess that Christ ascended above all the heavens. We conclude from this, and I hope very properly, that the happy realms of the blessed exist beyond the furthest sphere, where the bodies of the saints are to be placed next to Christ at their proper time. Nothing prevents these bodies from being surrounded by the purest air, or instead of that, by some other body so that they are not lacking their own place. Or they may pass their time without being surrounded by an external body provided they retain their distances, relationships, arrangements, members and limits, because we are not so peevish or worried about a surrounding body that we would say that it is absolutely required.... For us it should be enough that Scripture calls them places because Christ says, 'In my Father's house there are many rooms," and because he said to his disciples, "I go and prepare a place for you.'... But this we urge, that the human body, whether it has the divinity joined to it [i.e., Christ's] or does not have it [i.e., the saints], can't exist in our world without occupying a place and being encircled by a surrounding body, unless maybe somebody wants to set up a vacuum in this world... I say that it's absolutely impossible for that object [a human body] not to be locally in a place." Orothetes continued (p. 116): "Therefore it is beside the point, not to say inept, for you to ask if these places are to be situated at the North or South Pole, as if beyond the eighth, or ninth, or tenth sphere, there do not lie vast spaces glowing in an incredible and gentle light, which are not shut in by either the North or South Pole, and since they are not carried about by a daily rotation they afford a solid and fixed dwelling place for the saints. It is indeed suitable that the inapproachable light be there, which the Father inhabits and which the Christ enjoys."

[83] For recent scholarship on Lutheranism and early modern science see footnote 90 on page 411. It is interesting to observe that if the Lutheran receptivity to new cosmologies depended in part on the real presence—glossed as the ubiquity of Christ, sprinkled liberally with appeals to God's absolute power, with a concomitant indifference to traditional interpretations of physical statements in the scriptures—then modern-day Lutherans such as John Warwick Montgomery demonstrate an analogous receptivity to unconventional systems of geology. Sprinkling his writings liberally with appeals to God's absolute power, and distrustful of traditional schemes of reconciling Genesis 1 with the antiquity of the Earth, Montgomery himself has climbed Ararat at least twice in search of Noah's Ark; John Warwick Montgomery, *The Quest for Noah's Ark* (Minneapolis: Bethany Fellowship, 1972,1985). Lutherans have been disproportionately influential in the creationist movement, with leading scholars such as Johann Friedrich Karl Keil (1807–1888) upholding a young Earth and 24-hour day hexameral interpretation through the nineteenth century, pastors such as Byron Nelson working side-by-side with Seventh-Day Adventists in the early twentieth-century, and scientists such as Paul Nelson (Byron's son) playing a major role in founding the intelligent design movement of the late twentieth century. Cf. Johann Keil, *Biblical Commentary on the Old Testament* (Edinburgh: T. & T. Clark, 1864–1901); Byron Christopher Nelson, *The Creationist Writings of Byron C. Nelson*, ed. Paul Nelson, Creationism in Twentieth-Century America: A Ten-Volume Anthology of Documents, 1903–1961, ed. Ronald L. Numbers, no. 5 (New York: Garland Publishing, Inc., 1995).

prising that such theological topics raised by the hexameral tradition were especially prominent in both cosmic sections and global representations.

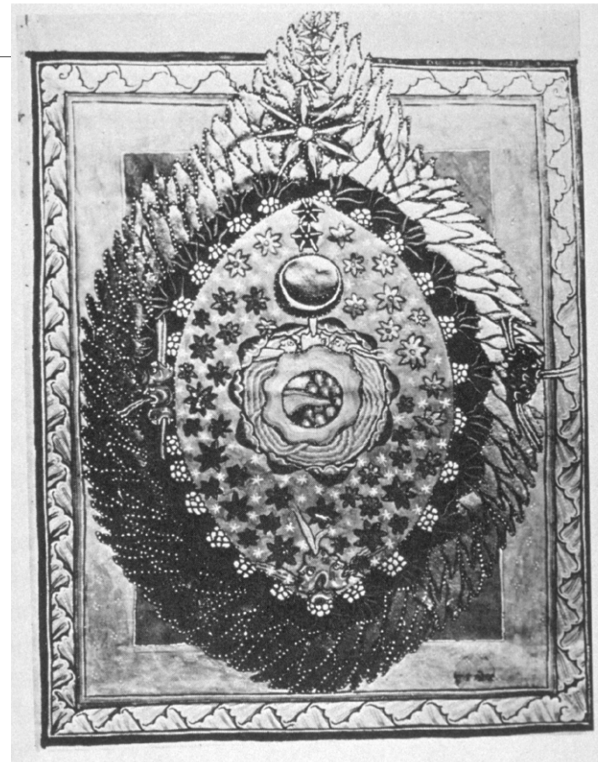
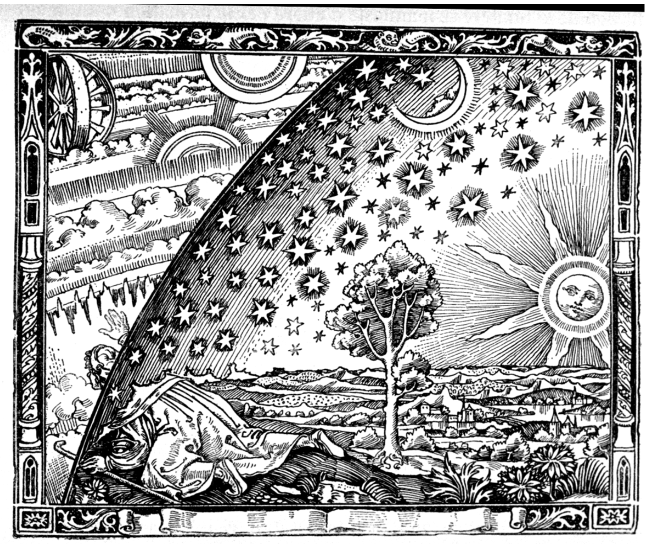


FIGURE 58. Hildegard of Bingen's ovoid cosmic section. *Scivias*, 12th century.

By no means were cosmic sections before the seventeenth century uniformly Ptolemaic, like Apian's. A non-Aristotelian cosmic section in the twelfth century illustrated the universe as envisioned by Hildegard of Bingen (ca. 1098–1180; Figure 58). "After this I saw a vast instrument, round and shadowed, in the shape of an egg...." So begins the third vision of Hildegard's *Scivias*. Hildegard's quite un-Aristotelian vision shows the terraqueous globe of dry land and the sea in the center, surrounded by regions of air and clouds, which are roughly spherical like the Earth they cover. Above the clouds the Moon (conventionally depicted as an illuminated crescent superimposed upon a full disk) revolves in a zone of purest ether with two planets (Venus and Mercury) holding it in its place. The fixed stars are scattered in the same ethereal zone, receiving the brightness of the Moon as it periodically empties itself among them before moving back beneath the fiery Sun to regain its light. Beyond the fixed stars lies a realm of "dark fire," shaken with thunders, tempests, and many sharp stones. Above the dark fire in a realm of "bright fire" turns the Sun, which illuminates the entire cosmos. In the region of bright fire, three outer planets (Mars, Jupiter and Saturn) hold up the Sun and prevent it from sinking downward. Within each realm of clouds, ether, dark fire and bright fire are many whirlwinds, symbolized by four triads of faces. The contention of the whirlwinds makes the Earth quake. Hildegard's cosmos was emblematic, presented as a visible manifestation of the invisible realities of the Trinity (bright fire), the Devil (dark fire), the church (the Moon and ether), baptism (clouds), and the weaknesses of miracle-shaken humanity (the Earth).[84]

FIGURE 59. Camille Flammarion, *L'Atmosphère* (1888). HSCI.

Caption. "Un missionnaire du moyen âge raconte qu'il avait trouvé le point où le ciel et la Terre se touchent..."



Un missionnaire du moyen âge raconte qu'il avait trouvé le point où le ciel et la Terre se touchent...

Although in Hildegard's emblem the universe is depicted as ovoid, the central Earth is still spherical, unlike an often-reprinted woodcut illustrating an alleged medieval belief in a flat, disc-shaped Earth (Figure 59).[85] Her spherical Earth should not be surprising; as Jeffrey Burton Russell has argued, the real medieval flat Earth myth is not that medievals believed in a flat Earth, but that moderns believe that they did.[86] Of course, if the Earth were regarded as flat, a global (rather than disc) view would make little sense and a global section would be impossi-

[84] See Hildegard of Bingen, *Scivias*, trans. Columba Hart and Jane Bishop, introduction by Barbara J. Newman and Preface by Caroline Walker Bynum, Classics of Western Spirituality, ed. Bernard McGinn (New York: Paulist Press, 1990), 91–98. In later life Hildegard adopted a spherical (but no more Aristotelian) cosmos, claiming that her former vision was only a spiritual picture and not a physical manifestation. See Hildegard of Bingen, *Book of Divine Works with Letters and Songs* (Santa Fe, New Mexico: Bear and Company, 1987), 22–24. Cf. Charles Singer, "The Scientific Views and Visions of Saint Hildegard (1098–1180)," in *Studies in the History and Method of Science,* ed. Charles Singer, 2 vols. (Oxford: Clarendon Press, 1917; reprint New York: Arno Press, 1975), vol. 1, 1–55.

[85] Figure 59 is used to illustrate medieval belief in a flat Earth by J.D. Bernal and Daniel Boorstin, among others, who attribute it to the sixteenth and seventeenth centuries respectively. It first appeared, however, in Camille Flammarion, *L'Atmosphere: Météorologie Populaire* (Paris, 1888), p. 163. For references and additional examples and commentary see Kerry Magruder, "This is not a medieval woodcut," *http://www.earthvisions.net/flat_earth.htm*.

[86] This is conveniently documented and analyzed by Jeffrey Burton Russell, *Inventing the Flat Earth: Columbus and Modern Historians* (New York: Praeger, 1991).

ble. The use of surface views to depict the Earth in cosmic sections such as Apian's or Hildegard's has nothing to do with an alleged belief in a flat Earth.

Cosmic sections provided an occasion for the portrayal of miniature global sections and global views in large part because of their frequent use to illustrate the first chapter of Genesis. At the beginning of the creation week, most illustrators employed meteorological sections to portray the elemental regions at the center of the world. For a typical example consider a series of hexameral illustrations from the *Liber Chronicarum* (1493), a popular early printed work often known as the *Nuremberg Chronicle*. This illustrated history extending from the creation to the apocalypse includes a cosmic or meteorological section for each of the first four days (Table 48). Figure 62 depicts all five Aristotelian elements (earth, water, air, fire, ether) in separate concentric regions (although only the outer two regions are pure). Yet by the end of the creation week the meteorological regions accommodate an organized, habitable, terraqueous globe, as shown in the cosmic section depicting the seventh day (Figure 68). Global surface views were often used to depict the end result of the primordial separation between the dry land and the sea. Meteorological sections without a terraqueous global view typically appear in cosmic sections when the Earth and universe are depicted before the completion of the third day. Such representational conventions reflect an enduring hexameral vision, as we shall see in the more detailed examples comprising the remainder of this chapter.[87]

[87] Hartmann Schedel, *Liber chronicarum* (Nuremberg: Anton Koberger, 1493). The *Liber Chronicarum* of Schedel (1440–1514) contains over 2000 woodcuts, some handcolored, created under the supervision of William Pleydenwurff (d. 1494) and Michael Wolgemut (1434-1519). Albrecht Dürer was Wolgemut's godson and apprentice, and participated in the team of artists that created the woodcuts. For an insightful discussion of these illustrations in the context of Renaissance hexameral idiom see S. K. Heninger, Jr., *The Cosmographical Glass: Renaissance Diagrams of the Universe* (San Marino, California: Huntington Library, 1977), 17–20. The importance of the terraqueous globe in the meteorological tradition (in addition to the four concentric sublunar regions) is discussed above in "Were theories of the Earth Inconceivable in Pre-Copernican Cosmologies?," beginning on page 228. An exception to the generalization that post-third day depictions are usually global views instead of global sections occurs with illustrations of the subterranean geography of hell. An example of a cosmic section noting a fiery hell in the center of the Earth is held by the British Library, Arundel Ms. 83 f.123r, and reproduced in Whitfield, *Landmarks,* color plate facing page 33.

TABLE 48. Nuremberg Chronicle (1493), Hexameral Sequence. HSCI.

FIGURE 60. *Nuremberg Chronicle*, *In principio*.

Explanation. In the beginning, God created the Heavens with the angelic host.

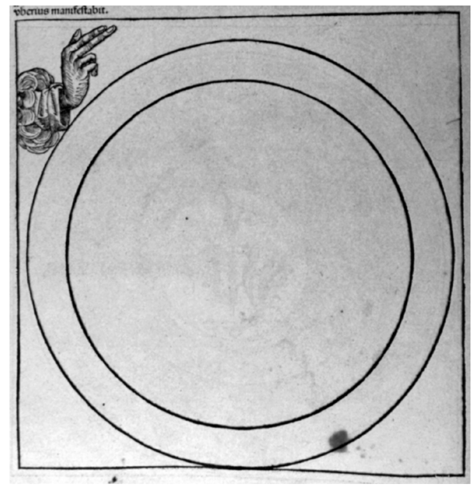


FIGURE 61. *Nuremberg Chronicle*, Day 1.

Explanation. Day 1. God said, "Let there be light." This resulted in an ethereal realm of light (the waters above) and a dark realm of elemental chaos (the waters below).

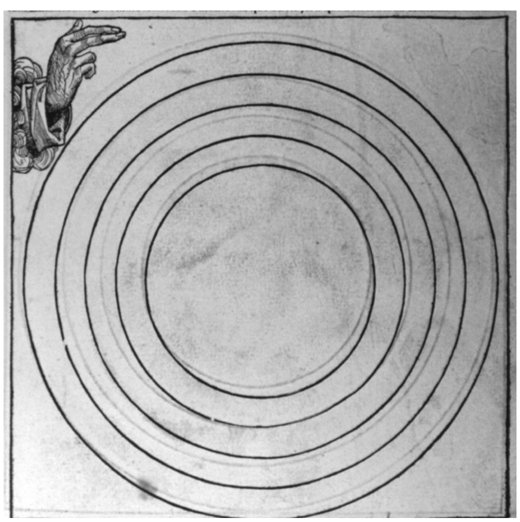


FIGURE 62. *Nuremberg Chronicle*, Day 2.

Explanation. The outer region represents the waters above, understood as invisible, solid crystalline spheres. The waters below consist of three lower (meteorological, sublunar) regions: an upper fiery region which is pure, unmixed and heated by the motions of the spheres (the *spera ignis* of Figure 68); a middle region of air (the *spera aris* of Figure 68); and a lower region which is impure and mixed.

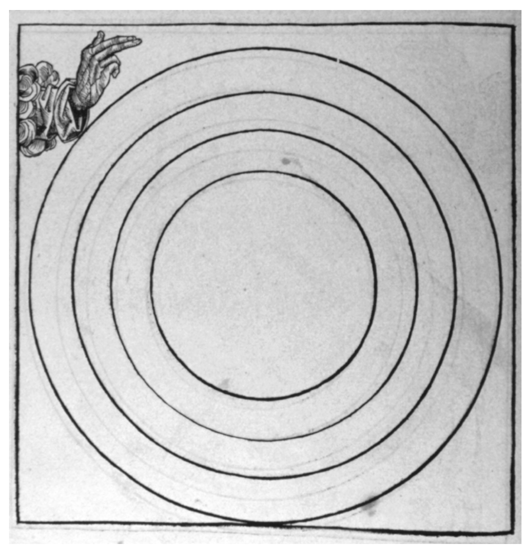


FIGURE 63. *Nuremberg Chronicle*, Day 3.

Explanation. The three meteorological regions at the beginning of the third day correspond to the sublunar area of Figure 64 and Figure 68. By the end of the third day the lower waters gather together to form the seas as shown in the central global view of Figure 64 and Figure 68. (The *spera aque* of Figure 68 is the lower realm of air which contains the clouds.)

TABLE 48. Nuremberg Chronicle (1493), Hexameral Sequence. HSCI.

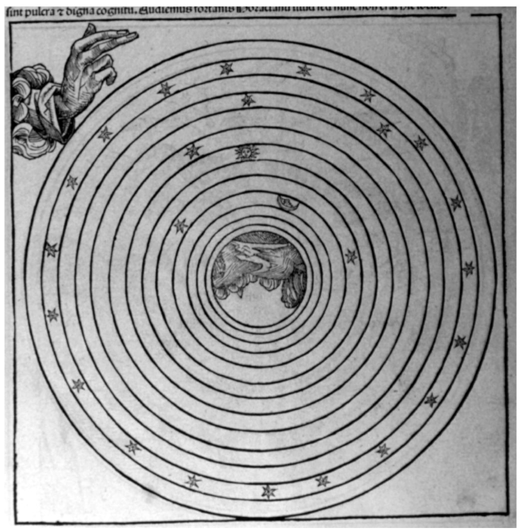


FIGURE 64. *Nuremberg Chronicle*, Day 4.

Explanation. The outer ethereal region of Figure 62 is now divided into multiple crystalline spheres containing the Moon, Sun, planets and fixed stars. Beneath the Moon are the three meterological regions of Figure 63 and the terraqueous globe.

FIGURE 65. *Nuremberg Chronicle*, Day 5.

Explanation. Just as the "waters above" divided on Day 1 were filled on Day 4, so the "waters below" divided on Day 2 are filled on Day 5 with the creation of birds and fish.

FIGURE 66. *Nuremberg Chronicle*, Day 6.

Explanation. Creation of Adam in the divine image from the dust of the ground (Genesis 2). In the background, land animals fill the dry land divided from the seas on Day 3.

FIGURE 67. *Nuremberg Chronicle*, Day 6.

Explanation. Creation of Eve from Adam's side (Genesis 2).

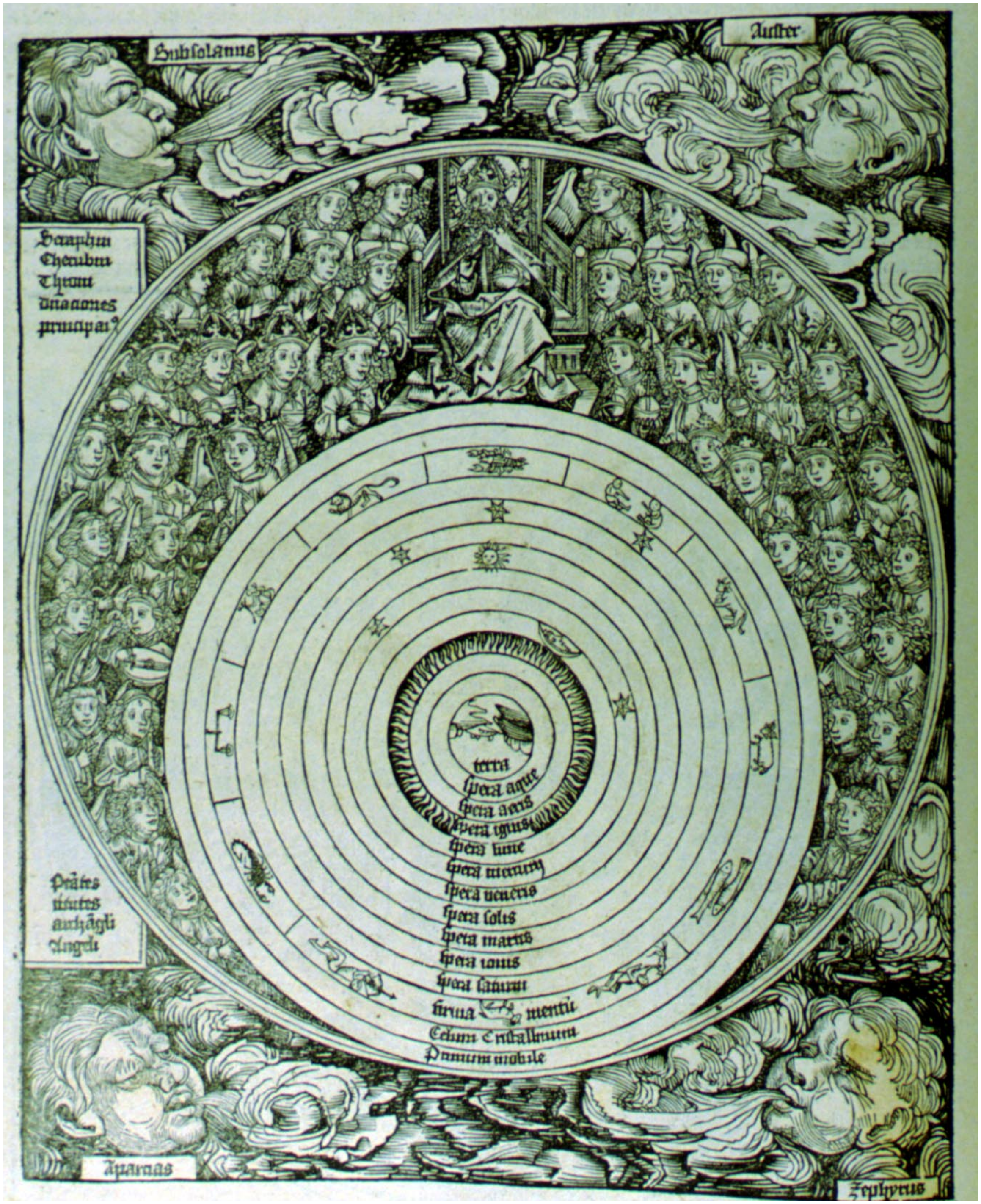


FIGURE 68. *Nuremberg Chronicle*, Day 7. HSCI.

Explanation. Cosmic section for the seventh day of creation. The central terraqueous global view and the three sublunar meteorological regions correspond to the completion of the work of the third day, while the filling of the ethereal spheres was the work of the fourth day. The four winds in the corners perpetuate meteorological changes. The sphere of fixed stars is identified as the firmament. To sanctify the seventh day, the Deity reposes on his heavenly throne amidst the orders of angelic beings enumerated on the left.

§ 6-i. Ptolemaic and Copernican sections of Leonard and Thomas Digges

Two cosmic sections from a mid-sixteenth-century work offer an interesting comparison of a Ptolemaic cosmic section by a father, Leonard Digges (Figure 69), with a Copernican cosmic section by his son, Thomas Digges (Figure 70).[88] Leonard Digges referred to his astro-meteorology as a "Prognostication generall, foreuer to take effect," and included a long section of advice for "What is to be chosen or auoyded vnder euery aspect of the Moone."[89] Citing Melanchthon and others, Leonard began by defending the mathematical sciences.[90] When discussing the traditional natures, influences, and periods of the planets, Leonard justified the inclusion of a Ptolemaic section on didactic grounds:

> For more plainnesse of that which is opened, now shall follow a figure, by the which ye may perceive how the Orbe of the one Planet compasseth the other. Also, how these Planets are placed in the heauen; yea, which Planet is highest from

[88] Leonard Digges and Thomas Digges, *A Prognostication Euerlasting of Right Good Effect, fruitfully augmented by the Author, containing plaine, briefe, pleasant, chosen rules to iudge the weather by the Sunne, Moone, Starres, Comets, Rainbow, Thunder, Clowdes, with other extra-ordinary tokens, not omitting the Aspects of Planets, with a briefe iudgement for euer, of Plentie, Lacke, Sickness, Dearth, Warres, &c. opening also many naturall causes worthie to be knowne. To these and other now at the last, are ioyned diuers generall pleasant Tables, with many compenius Rules, easie to be had in memorie, manifold wayes profitable to all men of vnderstanding. Published by Leondard Digges Gentleman. Lately corrected and augmented by Thomas Digges his sonne* (originally published London: Imprinted by Thomas March, 1576; these images and quotations taken from the later edition, London: Felix [Kunastone?], 1605). Hereafter "Leonard Digges, *Prognostication*," or "Thomas Digges, "The Addition."

[89] Leonard Digges, *Prognostication,* beginning on p. 17. On Renaissance astro-meteorologies see Mary Ellen Bowden, "The Scientific Revolution in Astrology: The English Reformers, 1558-1686" (Ph.D. dissertation, Yale University, 1974); John Wands, "The Theory of Climate in the English Renaissance and *Mundus Alter et Idem*," in *Proceedings of the Fifth International Congress of Neo-Latin Studies* (Binghampten, New York: Medieval and Renaissance Texts and Studies, 1986), 519–525; and H. G. Körber, "The Views on the Formation of Winds in the Geocentric and Heliocentric Conception of the Universe," *Studia Copernicana* 14 (1975): 185–191. Victor Thoren cited Mary Ellen Bowden's study of the discarding of the Aristotelian fiery sphere in astrometeorologies as "one of the most critical breakthroughs of the sixteenth century." Victor E. Thoren, *The Lord of Uraniborg: A Biography of Tyche Brahe* (Cambridge: Cambridge University Press, 1990), 301.

[90] Leonard Digges, *Prognostication,* 3. On Melanchthon's attitudes toward astronomy and astrology see Sachiko Kusukawa, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon,* Ideas in Context, ed. Quentin Skinner, Lorraine Daston, Wolf Lepenies, Richard Rorty and J. B. Schneewind, no. 34 (Cambridge: Cambridge University Press, 1995); and Charlotte Methuen, "The Role of the Heavens in the Thought of Philip Melanchthon," *Journal of the History of Ideas* 57 (1996): 385–404. On Lutheran attitudes toward natural knowledge in the sixteenth century, see John Warwick Montgomery, "Cross, Constellation, and Crucible: Lutheran Astrology and Alchemy in the Age of the Reformation," *Ambix* 11 (1963): 65–86.

> the earth, and which neerest vnto vs. Consider wel this figure, so needeth no farther declaration.[91]

Much like Apian's Ptolemaic section, in Figure 69 observe concentric layers of the heavenly spheres, from the habitation of God and the elect down to the Earth at rest in the center. Like Apian, the elder Digges adopted a ten-sphere system of seven planets surrounded by three other spheres: the firmament of fixed stars, the crystalline heaven, and the first mover.[92]

91 Leonard Digges, *Prognostication,* 15.

92 The count is his own; "tenne orbes." Francis Johnson has shown how the number of spheres was an important question often discussed by sixteenth-century astronomers. In the early 1200s Sacrobosco specified nine spheres; the *primum mobile,* firmament of fixed stars, and the seven planetary spheres; Caspar Peucer's *Elementa doctrinae de circulis coelestibus et primo motu* represents an updated sixteenth-century nine-sphere system. Shortly after Sacrobosco, however, the Spanish scholars who compiled the Alfonsine tables added a tenth sphere to account for the "trepidation of the equinoxes" believed by Thabit Ibn Qura to account for a discrepancy between the values obtained for the precession of the equinoxes by Ptolemy and Al-Bitruji (Albategenus). This ten-sphere tradition, including trepidation, is that of both Apian and Leonard Digges. A system of eight spheres, dispensing altogether with orbs above the fixed stars, was advanced by Augustinus Ricius in *De motu octave sphaerae* (1513), and defended by Oronce Finé in *De mundi sphaera sive cosmographia* (1542) and by Robert Recorde in *Castle of Knowledge* (1556); this system denied trepidation, and assigned precession to the sphere of fixed stars, thus avoiding the postulation of any orb not containing a visible body. Eleven-sphere systems appeared in works by Christoph Clavius and others (not necessarily Copernicans) toward the end of the sixteenth century to accommodate an additional motion attributed to the Earth's axis by Copernicus. Cf. Francis R. Johnson, "Astronomical Text-books in the Sixteenth Century," in *Science, Medicine, and History,* ed. E. Ashworth Underwood, vol. 2 (Oxford: Oxford University Press, 1953), 285–302.

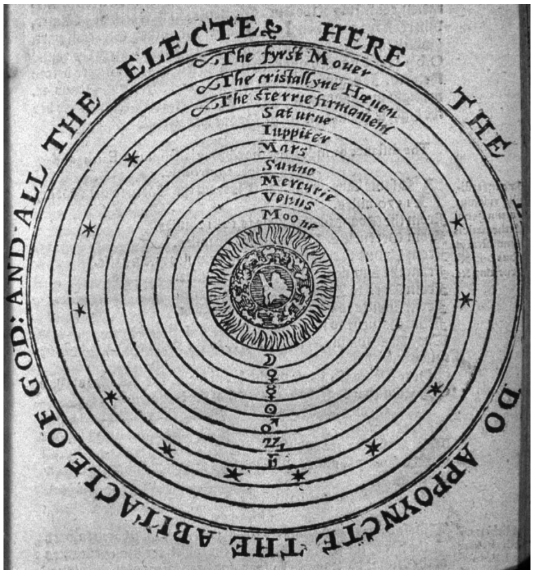


FIGURE 69. Leonard Digges, Ptolemaic Section[a]

Caption. "Here the [Learned] Do Appoyncte the Abitacle of God: And all the Electe." (original page cropped in the HSCI copy)

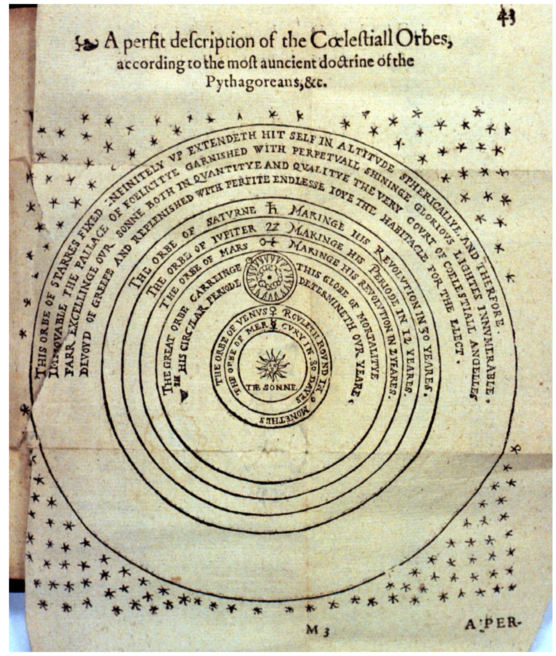


FIGURE 70. Thomas Digges, Copernican section[a]

Caption. "A perfit description of the Coelestiall Orbes, according to the most auncient doctrine of the Pythagoreans, &c."

Explanation. Figure 70 outer orb: "This orbe of starres fixed infinitely up extendeth hit self in altitude sphericallye, and therefore immovable the pallace of foelicitye garnished with perpetuall shininge glorious lightes innumerable, farr excellinge our sonne both in quantitye and qualitye the very court of coelestial angelles devoid of greefe and replenished with perfite endlesse love the habitacle for the elect."

Explanation. Figure 70 Earth: "The great orbe carryinge this globe of mortalitye with his circular periode determineth our yeare."

a. Leonard Digges and Thomas Digges, A Prognostication Euerlasting of Right Good Effect, fruit.... Lately corrected and augmented by Thomas Digges his sonne (originally published London: Imprinted by Thomas March, 1576; these images are taken from a later edition, London: Felix [Kunastone?], 1605). HSCI.

Ostensibly Thomas Digges re-issued his father's treatise because he discovered numerous printing errors, but in his notice to the reader, Thomas Digges reported coming across the Ptolemaic "Modill of the world" of his father, which he could not let pass uncorrected.[93] Thomas Digges unabashedly argued for the physical truth of Copernicanism based on mathematical demonstrations, invoking Copernicus' own language and rhetoric to make the case that the Earth "resteth not in the Centre of the whole world," but only

> in the Centre of this our mortall world or Globe of Elements, which environed and enclosed in the Moones Orbe, and together with the whole Globe of mortalitie is caried yeerely round about the Sunne, which like a king in the middest of al raigneth and glueth lawes of motion to the rest, sphaerically dispersing his glorious beames of light through all this sacred Coelestial Temple.[94]

In transposing the positions of the Sun and the Earth, the meteorological regions and the Moon stay with the Earth. In Figure 70 the Earth continues to be surrounded by clouds and an outermost sphere of fire (just below the Moon), as if the meteorological section were transported entire into the heavens. "The Globe of Elements enclosed in the Orbe of the Moone, I call the Globe of Mortality, because it is the peculiar Empire of death."[95] It is not only gravity and levity which hold the elemental regions together: several decades before William Gilbert's *De magnete* (1600), Thomas Digges associated the Earth's magnetism with its ability to hold the spheres of elements around it as it moves through space.[96] Not only was the meteorological tradition important for shaping conceptions of the Earth prior to Copernicus, but with its notion of the integrity of the sublunar realm it may have facilitated the reception of Copernicanism as well.

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[93] On Thomas Digges see Francis R. Johnson and Sanford V. Larkey, "Thomas Digges, The Copernican System, and the Idea of the Infinity of the Universe in 1576," *Huntington Library Bulletin* 5 (1934): 69–117, which reprints Digges' supplement to the *Prognostication euerlastinge* and discusses Digges' earlier Copernican pronouncements in *Alae seu Scalae Mathematicae* (1572), a work about the 1572 nova appearing in Cassiopeia. Also see Francis R. Johnson, *Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645* (Baltimore: Johns Hopkins University Press, 1937), especially chs. 4, 6 and 7.

[94] Thomas Digges, "To the Reader," p. M verso. Digges' advocacy of the physical truth of Copernicanism is captured in the title of his lengthiest section, "A Perfit Description of the Coelestiall Orbes, according to the most ancient doctrine of the Pythagoreans: lately reuiued by Copernicus, and by Geometriall Demonstrations approued," beginning on p. 3, facing Figure 70.

[95] Thomas Digges, "To the Reader," p. M2 verso.

[96] "In the middest of this Globe of Mortality hangeth this dark star or ball of the earth and water, balanced and sustayned in the middest of the thinne ayre onely with what proprietie which the wonderfull workeman hath giuen at the Creation to the Center of this Globe, with his magnetical force vehemently to draw and hale vnto it selfe all such other Elemental things as retayne the like nature." Thomas Digges, "To the Reader," p. M2 recto. Digges returned to the theme of the Earth's magnetism in a separate section devoted to navigation, "An Hypothesis or supposed cause of the variation of the Compasse, to be Mathematically weied," "The Addition," p. D2 verso.

Despite his Copernicanism, Thomas Digges maintained the traditional meaning of the empyrean heaven as the dwelling place of God and the elect. His utter conservatism on this point is in fact just as remarkable as his much-lauded originality in depicting an infinite cosmos, for they were accomplished in one and the same act.[97] Digges combined the empyrean realm (traditionally immovable) with the firmament of fixed stars (immovable in the Copernican system), and this required that he immensely extend the latter.[98] The outer orb is misleadingly drawn as a separate sphere in Figure 70, for according to its label it refers to the entire area full of stars extending infinitely up (like Gilbert's stellar realm in Figure 71 on page 417): "The first and biggest of all is the immoueable sphere of fixed starres, containing it selfe and all the rest, and therefore fixed: as the place uniuersall of rest...."[99] According to Digges we will:

[97] Typical in its emphasis on Digges' originality in this respect is the comment of Johnson: "Digges had the courage to break completely with the older cosmologies by shattering the finite outer wall of the universe. He was the first modern astronomer of note to portray an infinite, heliocentric universe, with the stars scattered at varying distances throughout infinite space." Francis R. Johnson, *Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645* (Baltimore: Johns Hopkins University Press, 1937), 164–165. On the other hand, a number of continental Copernicans were making similar claims about the indefinite immensity of the sphere of stars, and the text of Copernicus itself implied that the heavens were indefinitely immense relative to the size of the Earth and the diameter of its revolution (*De revolutionibus*, Book I, chapter 6).

[98] Cf. the comments of Peter Martyr as "Orothetes" in footnote 82 on page 404.

[99] Thomas Digges, "The Addition," p. N verso. Johnson points out that Digges also endorsed the idea of a plurality of inhabited worlds as advanced by the Neoplatonic educator Palingenius; cf. Francis R. Johnson, *Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645* (Baltimore: Johns Hopkins University Press, 1937), chapter 5 and p. 163. Although one might think that the plurality of worlds leads to a contradiction with Digges' identification of the realm of the stars with the empyrean heaven, that is not necessarily the case. I have not found this question explicitly addressed by Thomas Digges, but the plurality of worlds would become compatible with the hexameral idiom identified here on the assumption that the empyrean worlds are either unfallen, already redeemed, mansions prepared for the elect, or some combination of the three. On the other hand, if fallen, they might lie in quarantine like the Earth as a "sphere of mortality," although this possibility would de-center the diagram, making it at least theoretically possible to draw a similar diagram for every star. The visual conventions of the diagram are too flexible to constrain interpretation on this point, but would seem slightly more consistent with the view that we are not in the empyrean, and that other worlds which are depicted within the empyrean are therefore not presently in a fallen state. Clearly Digges had little to gain in this work by openly exploring these controversial issues. For more on Digges specifically see Francis R. Johnson and Sanford V. Larkey, "Thomas Digges, The Copernican System, and the Idea of the Infinity of the Universe in 1576," *Huntington Library Bulletin* 5 (1934): 69–117. For a general discussion see "The Heliocentric Theory, Scripture, and the Plurality of Worlds," chapter 4 of Steven J. Dick, *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge: Cambridge University Press, 1982), and Dick's discussion of William of Vorilong, pp. 42–43.

> neuer sufficiently be able to admire the immensitie of the rest: especially of that fixed Orbe garnished with lights innumerable, and reaching up in Sphericall Altitude without ende.... the glorious Court of the great God, whose unsearchable works invisible we may partly by these his visible, conjecture: to whose infinite power and maiestie, such an infinite place surmounting all other both in quantitie and qualitie only is conuenient.[100]

These theological motives of immovable rest and infinite majesty, by stipulating a combination of the empyrean with the realm of fixed stars, mitigated potential empirical objections to Copernicanism deriving from a lack of observable stellar parallax.[101]

Alternative cosmologies proliferated in the sixteenth and seventeenth centuries (not all of which relied upon hexameral idiom), and the Tychonic system (discussed in the next section) was not the only new cosmology that was geocentric. In *De magnete* (1600), Wiliam Gilbert advocated a magnetic cosmology in which the Earth rotates on its axis every twenty-four hours.[102] Speaking of English natural philosophers in the first decades of the seventeenth century, Johnson explained:

> the more conservative among the scientific writers supported a geocentric system which combined the rotating magnetic Earth of Gilbert with the arrangement of the planets proposed by Tycho Brahe. It was Tycho's system, or the modification of it made by the followers of William Gilbert, that was opposed to the Copernican system in all the important English astronomical treatises after 1600.[103]

[100]Thomas Digges, "The Addition," p. 2 verso.

[101]Johnson explains: "Worse still, systematic observation of the nova of 1572 rudely dashed the hopes, which Copernican adherents such as Thomas Digges had evoked, of discovering a proof of the Copernican theory by measuring the parallax of that star.... Since the sixteenth-century astronomers failed to detect any parallax with the then existing instruments, Copernican supporters were forced to postulate an incredibly huge distance between the orbit of Saturn and the fixed stars." Francis R. Johnson, "Astronomical Text-books in the Sixteenth Century," in *Science, Medicine, and History*, ed. E. Ashworth Underwood, vol. 2 (Oxford: Oxford University Press, 1953), 286–287.

[102]Duane H. D. Roller, *The De magnete of William Gilbert* (Amsterdam: Menno Hertzberger, 1959) has very little to say of Gilbert's cosmology, on which see Sister Mary Suzanne Kelly, "The *De Mundo* of William Gilbert" (Ph.D. dissertation, University of Oklahoma, 1961). Cf. the description of the terrella as a model Earth in footnote 46 on page 386.

[103]Francis R. Johnson, *Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645* (Baltimore: Johns Hopkins University Press, 1937), 220.

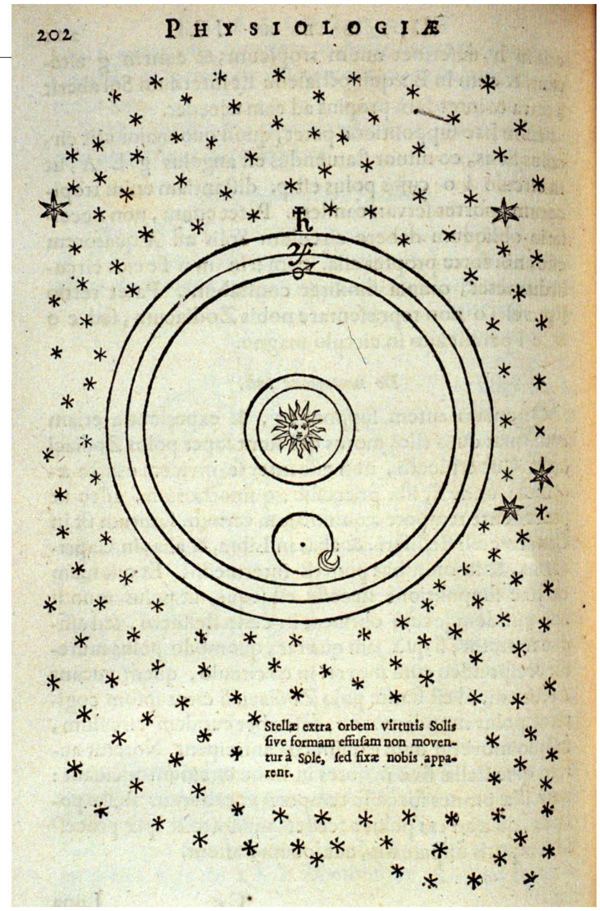

FIGURE 71. William Gilbert, *de Mundo* (1651), p. 20.

Caption. "Stellae extra orbem virtutis Solis sive formam effusam non moventurà Sole, sed fixae nobis apparent," or "Stars diffused without form beyond the orb of virtue of the Sun do not move around the Sun, but to us appear fixed."[104]

Description. Cosmic section, consistent with (but not explicitly supporting) Copernicanism. HSCI.

A posthumously-published work, which circulated in manuscript form among Gilbert's friends prior to his death, contains a cosmic section (Figure 71) in which the realm of fixed stars is reminiscent of Thomas Digges' Figure 70. Despite their common interests in magnetism and meteorology there are two apparent contrasts to the younger Digges, for Gilbert's arguments privileged evidence from magnetic experiments without appealing to hexameral idiom. In addition, Gilbert was reticent in committing to Copernicanism, conspicuously failing to indicate in the diagram whether the Earth orbits the Sun or the Sun revolves around the Earth.[105]

[104]William Gilbert, *De Mundo nostro Sublunari Philosophia Nova,* ed. Gvilielmi Boswelli (Amstelodami: Apud Ludovicum Elzevirium, 1651), 202.

[105]Notice how Gilbert invokes the Moon in order to avoid asserting or denying the revolution of the Earth in the following sentence, which is typical of his circumspection: "But if [heavenly bodies] have a motion, it will be motion of each round its proper centre, like the earth's rotation; or it will be by a progression in an orbit, like that of the moon...." Gilbert, *De magnete*, 320.

§ 6-ii. The Tychonic-Hexameral Cosmic Vision of Gabriele Beati

We have seen in the case of Leonard and Thomas Digges that hexameral discourse could bridge the gap between Ptolemaic and Copernican cosmologies in part by facilitating appreciation of the immensity of the region of fixed stars, but how significant was hexameral discourse for other cosmological views? Many figures would provide insightful examples, but the shaping of cosmology by hexameral discourse is splendidly manifest in the *Sphaera Triplex* (1662) of Gabriele Beati (1607-1673), a Professor of Mathematics at the *Collegio Romano*. Baldini and Coyne heuristically suggest that two Jesuit traditions, one physical (following many of the views of Robert Cardinal Bellarmine, 1542–1621) and the other mathematical-astronomical (following the assumptions and techniques taught by Christoph Clavius, 1538–1612) converged at mid-century in the work of Giovanni Battista Riccioli (1598–1671). Beati's mathematical textbook compactly represents this fusion a decade after Riccioli's *Almagestum novum* (1651), presenting four major features representative of mid-century Jesuit cosmology:

- justification of cosmological assertions by means of hexameral evidence,
- holding the number of heavens to be three,
- the rejection of solid planetary orbs and
- the adoption of the Tychonic system.

The first three were upheld by Bellarmine and others in the physical tradition, the third by Clavius and the latter two by others in the mathematical-astronomical tradition. All four characteristics are illustrated in Beati's fold-out cosmic section (Table 49).[106]

Like Riccioli and other mathematical-astronomical Jesuits after Clavius, Beati upheld a Tychonic cosmology in which the Earth is at rest in the center of the universe and the Sun revolves around the Earth once each year. Interestingly, Beati organized his exposition of the Tychonic system explicitly according to hexameral chronology. This was by no means novel or idiosyncratic among Jesuit mathematicians. For example, Riccioli similarly began his consideration of "De Mvndi Systemate" with a much lengthier discussion of the works of the first four days of creation.[107] Much earlier Robert Bellarmine explicitly relied upon the hexameral writings of the Church Fathers, particularly St. Basil, in developing his cosmological views. Baldini and Coyne point out that Bellarmine argued for the fluidity of the heavens on the basis of hexameral exegesis *prior to* the appearance of the nova of 1572 (the first volume of Louvain lectures was completed before the end of August 1572, and the nova was first reported in November of the same year).[108] Edward Grant attributes the increasing prevalence of ideas of fluid heavens and celestial corruptibility in later scholasticism to the importance of patristic texts such as Basil's hexameral commentary which became more widely available in the sixteenth century.[109]

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[106]Gabrielis Beati, *Sphaera Triplex Artificialis, Elementaris, ac Caelestis; Varias Planetarum affectiones; & praesertim Motus, Facillime explicans* (Rome: Typis Varesij, 1662); hereafter "Beati, *Sphaera Triplex*." Beati's work is divided into three books; "De Sphaera Artificiali," "De Sphaera Elementari," and "De Sphaera Celesti." The present discussion of Beati is based on the third book of the *Sphaera Triplex* devoted to the celestial sphere, Chapter I, "De Corporibus Caelestibus in genere," Article I, "De Caelorum Natura," pp. 104–113. Most of the topics in Beati's single-volume octavo textbook were treated at much greater length in the folio work of his better-known Jesuit predecessor Riccioli; cf. Ioanne Baptista Riccioli, *Almagestvm Novvm,* Tomus Primus (Bononiæ: Ex Typographia Hæredis Victorij Benatij, 1651), hereafter "Riccioli, *Almagestvm Novvm*." On Bellarmine and the two traditions in Jesuit cosmology see Robert Bellarmine, *The Louvain Lectures (Lectiones Lovanienses) of Bellarmine and the Autograph Copy of his 1616 Declaration to Galileo*, ed. Ugo Baldini and George V., S.J. Coyne, Studi Galileiani, vol. 1, no. 2 (Specola Vaticana: Vatican Observatory Publications, 1984), 43, note 94; hereafter Bellarmine, *Louvain Lectures*. Baldini and Coyne discuss Bellarmine's skepticism toward the cardinal assumption of mathematical astronomy from Plato to Kepler that planetary motions should be explained by combinations of uniform circular motions; instead Bellarmine thought of the planets as moving through a stationary heaven (so that the Sun would follow an uncompounded spiral path), although he was not able satisfactorily to explain the paths of the other planets and fixed stars. Although this question provides the specific context for Baldini and Coyne's identification of two Jesuit traditions, their distinction may be heuristically generalized here to apply to the four major features of Beati's diagram. On Clavius see James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago: University of Chicago Press, 1994); hereafter, "Lattis, *Between Copernicus and Galileo.*"

[107]*Almagestvm Novvm,* Pars II, Liber IX, Sectio I, 193–246. Riccioli's section contains nothing similar to Beati's diagram (in either copy), yet Beati's exposition contains few arguments or ideas not found in Riccioli.

[108]Cf. Bellarmine, *Louvain Lectures,* 5 (on the 1572 nova), 8–11, *passim*. For a brief general account of the 1572 nova and its significance for the acceptance of fluid heavens see Lattis, *Between Copernicus and Galileo*, chapter 6. According to Baldini and Coyne, the prominence of hexameral interpretation in Jesuit cosmology also owed something to the Jesuit order of discussion of Aquinas.

[109]Edward Grant, *Planets, Stars and Orbs*, 267–268.

TABLE 49. Gabriel Beati, *Sphaera Triplex*, 1662

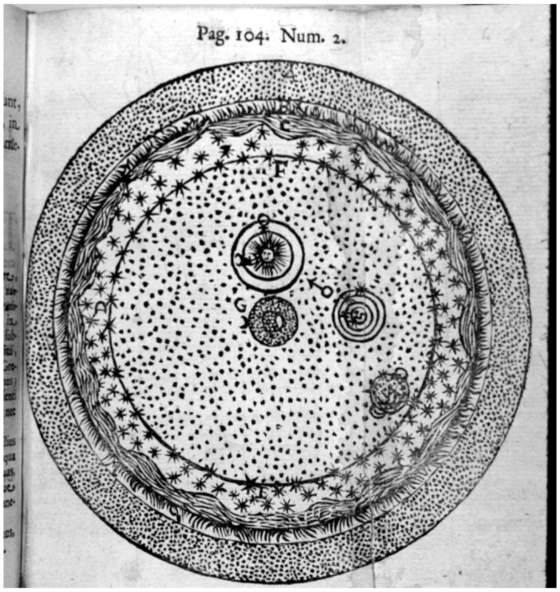


FIGURE 72. Beati, Ptolemaic positions, HSCI

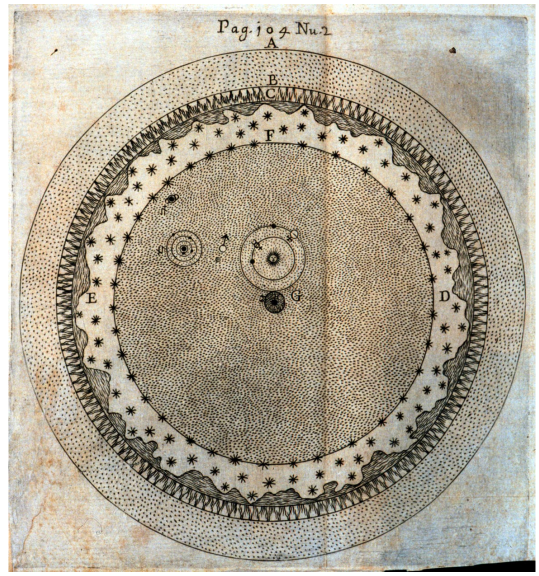


FIGURE 73. Beati, Tychonic positions, LH

Explanation. The three heavens according to Beati are labelled as follows:

3. Empyrean heaven	A, B, and C	
	Waters above the firmament: C	Waters above the firmament: between F & C
2. Firmament	Fixed stars or Caelum Syderum: between C & F	Fixed stars or Caelum Syderum: F
	Caelum Planetarum: between F & G	
1. Aereum	Region from the Moon down to the Earth	

Explanation. These two illustrations come from two copies of the same work published in the same year with identical text. Obviously the sections are neither Copernican nor Aristotelian. Both sections depict fluid heavens as upheld in both physical and mathematical Jesuit traditions. The Tychonic section (LH) is consistent with Beati's text and with the mathematical-astronomical Jesuit tradition after Clavius; the Ptolemaic section (HSCI) remains closer to the cosmology of Christoph Clavius, founder of Jesuit astronomy and a lifelong advocate of Ptolemaic cosmology.

Aside from the discrepant labels noted above, many other small details are drawn differently, including the Earth. The most interesting discrepancy between the two diagrams occurs with Saturn. Although drawn very small in the upper left on the LH version (enlarged in the thumbnail above right), Saturn lies in a position consistent with the Tychonic system Beati advocates (and is shown with handles or perhaps a ring). The depiction of Saturn in the lower right on the HSCI copy is odd in two respects. First, it is not drawn with three satellites as described in the text (see footnote 119). Second, it is placed in a Ptolemaic position as if it were revolving around the Earth, for its distance from the Sun is much too great to allow it to complete a revolution around the Sun with a constant radius.

The hexameral idiom embedded in these two diagrams, such as fluid heavens and the supercelestial waters, represents a continuity of discourse across Ptolemaic and Tychonic cosmologies.

Thus Beati related that on the first day God created the heavens, the Earth, and a vast and profound abyss of water. On the second day, in the middle of the water he made the firmament of fixed stars which divides the waters above from the waters below. This portion of the firmament, which Beati also called the *Caelum Sydereum* or sidereal heaven, revolves around the Earth once each day. Because this firmament is solid, the stars move together during this daily motion and the firmament is able to support the waters that lie above it. The waters above and below are aptly regarded as divided, Beati concluded, because elemental water cannot naturally cross the firmament which has a solid but igneous nature.[110] Contrary to Aristotle the firmament is not composed of a fifth element, because *aether* is simply another name for pure fire, the element naturally above the air.[111] Contrary to Aristotle there is no material dichotomy between heaven and Earth because the heavens consist of water and fire of the same nature as in the sublunar realm. Consequently, Beati held that the heavens are similarly corruptible—belief in the corruptibility of the heavens did not require commitment to a Copernican or Cartesian cosmology. It was known that, following the same logic, Bellarmine had argued for the igneous nature of the stars and the corruptibility of the heavens on the basis of hexameral exegesis and the tradition of the Church Fathers. Even Clavius argued for the corruptibility of the heavens after the nova of 1572; Riccioli likewise concluded that the visible heavens are corruptible.[112]

On the third day God prepared cavities in the surface of the Earth to hold the oceans, which temper subterranean heat and prevent the Earth from burning. In the same way and for the same reasons, Beati argued that God made cavities or receptacles in the outer surface of the solid firmament to hold the waters above, which likewise temper the heat of the firma-

[110]Beati, 105–111.

[111]Citing book II of Augustine's *Literal Meaning of Genesis*, Beati explained: "Caelum enumerat loco Elementi ignis. *Quattuor Elementa enumerata sunt, inquit, quibus mundus iste visibilis consurgit. Caelum scilicet, terra, aqua, & Aer.* Atque ita purus ignis, qui est supra aerem, dicitur Caelum, vocaturque in Scriptura, Aether, dum *prou* 8. dicitur: *quando Aethera firmabat sursum, & librabat fontes aquarum.* hoc est, dum partem firmamenti superiorem, solidabat, ad aquas super caelestes sustinendas." Beati, 108.

ment with its fiery stars. Indeed, it is possible to interpret the waters above the firmament in Table 49 as a literal depiction of the views of Basil.[113]

Following Bellarmine's hexameral studies, seventeenth-century Jesuits such as Riccioli widely adopted the convention of dividing the heavens into only three parts instead of the eight to eleven heavens of Peter Apian and other sixteenth-century astronomers.[114] Beati agreed that scripture provides support for only three heavens, pointing out that the firmament is referred to as a heaven in the first chapter of Genesis; the other two heavens are the Empyrean heaven and the *Aereum* or meteorological heaven.[115] The empyrean heaven consists of all that lies above or beyond the firmament; the habitation of angels and the blessed, it is apparently as spatial as the other depicted regions. Another heaven is the *Aereum*, which according to Genesis is the realm of the clouds (which are the cataracts of heaven) occupied by flying birds. Between the empyrean and the *Aereum* is the ***Caelum Planetarum***, the plane-

[112]On celestial corruptibility see Beati, 108-109; cf. Grant, *Planets, Stars and Orbs*, chapter 10. Beati cited Scheiner's work on sunspots to support the thesis of celestial corruptibility. With two major exceptions, Beati's views on the second day resemble Bellarmine's in Question 68 of the Louvain Lectures; cf. Bellarmine, *Louvain Lectures*, 10–18. The two exceptions are that Beati accepted that part of the firmament is solid, and that the firmament has a diurnal motion (as implied by the Tychonic system if the stars move together and the Earth does not rotate). Baldini and Coyne note that Scheiner publicized the fact that "Bellarmine, following the Scriptures and not Aristotle, has admitted the existence of water in the heavens, the future disintegration of the heavens, the igneous nature of the heavenly material," and that Bellarmine came to these conclusions not on the basis of "human understanding but on the divine word, not on his personal opinion but on the common thought of the Fathers...." All of the views Scheiner reported are of course defended in the Louvain Lectures. Cf. Bellarmine, *Louvain Lectures,* 27, note 5. On Clavius see Lattis, *Between Copernicus and Galileo*, 147–156. On Riccioli see *Almagestvm Novvm,* 238.

[113]Beati opted for the last position noted in this quotation: "velint, aquas illas, instar nebulae, rarefactas, ita firmamentum ambire, ut ibi maneant perpetuo suspensae, sicut in nostro aere, nebulae; Aliqui vero, ut Clemens, Beda, & alii, asserant, esse ad modum glaciei, vel Christalli, solidatas; Plerique tamen cum Ambrosio, Hilario, & aliis, volunt esse fluidas, includique in concavitatibus, ac receptaculis, à Deo in Extimà firmamenti superficiè factis, eo modo, quo aquae sublunares, includuntur in terrae concavitatibus, ibique esse positas, ad Syderum ardorem temperandum; sicut in terrae visceribus, à Deo sunt positi ignes subterranei, ad ipsius terrae frigus temperandum. Ad hoc autem requiritur, ut Caelum sit solidum." Beati, 110. Bellarmine followed Basil in suggesting that God formed fire by the rarefaction of water to make the firmament on the second day; Bellarmine, *Louvain Lectures*, 14. Basil regarded the vault of heaven as solid, and Bellarmine thought it was entirely fluid, so nothing occurs in Bellarmine, of course, like Beati's description of the hollowing out of basins in the firmament for the waters above.

[114]On sixteenth-century answers to the question of how many heavens exist see footnote 92 on page 412. Bellarmine identified three heavens from scripture—the *aereum, sydereum*, and *empyreum*—and argued that all the Fathers could be interpreted as agreeing with this numeration, although he conceded that scripture could allow for more if necessary. Cf. Bellarmine, *Louvain Lectures*, 16–17. Compare the language of Descartes in the *Principia philosophiae*; footnote 247 on page 551.

[115]Riccioli, *Almagestvm Novvm,* 224. Beati, 112, paragraph 20. Like Bellarmine and Riccioli, Beati supported this numeration with the scriptural report of Paul taken up to the third heaven.

tary heaven. Beati explained that the *Caelum Planetarum* is a fluid, inferior part of the firmament, undergoing daily motion like the fixed stars in the solid, superior *Caelum Sydereum*.[116]

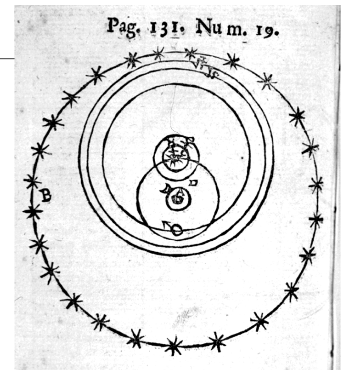


FIGURE 74. Beati, Tychonic system, p. 131. (Identical in both HSCI and LH copies.)

Unlike the Ptolemaic system where the planets revolve around the Earth, in the Tychonic system the planets revolve around the Sun.[117] Beati wrote that Venus, Mercury, and sunspots circle the Sun as if on epicycles,[118] while Jupiter with its four moons and Saturn with three satellites likewise revolve around the Sun.[119] As a result, the path of the Sun intersects the path of Mars (Figure 74). Since this would be impossible if the heavens were composed of solid crystalline spheres, therefore the *Caelum Planetarum* must be liquid, confirming the exegetical conclusion of Bellarmine ninety years before. Beati took care to justify this system from scripture, citing numerous hexameral commentaries by the Church Fathers to support the ideas that the heavens are fluid, corruptible, and both watery and fiery in nature. Thus

[116]Beati, 110. The second heaven thus extends from the outer edge of the *Aereum* to the inner edge of the empyrean; cf. Beati, paragraph 8, pp. 106-107.

[117]On Tycho's cosmology see Victor E. Thoren, *The Lord of Uraniborg: A Biography of Tyche Brahe* (Cambridge: Cambridge University Press, 1990).

[118]Roger Ariew has discussed the scholastic accommodation of the revolution of Mercury and Venus (and sunspots) around the Sun as implied by Galileo's observation of the phases of Venus in 1611: "late Scholasticism reacts to celestial novelties, makes adjustments to its theories, that is, changes and survives." Roger Ariew, *Descartes and the Last Scholastics* (Ithaca: Cornell University Press, 1999), 101. Cf. the non-Tychonic geocentric cosmic section of Jacques du Chevreul (1623) which shows Mercury and Venus on epicycles around the Sun published in Ariew, 104.

[119]Beati, 112. In Table 49 on page 420 Saturn appears with handles or perhaps a ring. Galileo observed Saturn in 1610 and concluded that it had two companions; later viewers described it as having ears or handles. Three years before Beati's text appeared, Christian Huygens proposed that Saturn was encircled by a ring (*Systema saturnium,* 1659). Huygens' observations and interpretations were opposed by the renowned telescope craftsman Eustachio Divini, *Brevis annotatio in systema Saturnium* (Rome, 1660; usually attributed to the Jesuit Honore Fabri), which proposed that Saturn is accompanied by multiple satellites, more consistent with Beati's text. Another round of exchanges followed with Huygens' *Brevis assertio systematis Saturnii sui* (The Hague, 1660) and Divini (Fabri), *Pro sua annotatione in systema saturnium* (Rome, 1661) until Fabri assented to Huygens' discovery of a ring in *Dialogi physici* (1665). Cf. Arthur Francis O'Donel Alexander, *The Planet Saturn: A History of Observation, Theory and Discovery* (London: Faber & Faber, 1962), chapter 4.

Beati had it both ways: a fluid firmament like Bellarmine and the Fathers, and a solid firmament to save the phenomena of the diurnal motion of fixed stars. The combination of both fluid and solid components of the firmament—a fusion of physical and astronomical Jesuit traditions—provided a convenient way for Beati to reconcile contradictory authorities. Following a lengthy survey of patristic views Riccioli had already come to the same resolution.[120]

In a mirror image of the firmament's division into one upper solid part and one lower fluid part, Beati divided the empyrean heaven into a lower solid part and an upper fluid part. The solid part, he explained, is required to support the glorified bodies of the blessed which are subtle but solid in nature.[121]

Thus hexameral ideas about the nature of the firmament (including its fluidity and solidity), the abodes of the saints, the empyrean heaven, and the waters above the heavens are encoded in these cosmic sections, and received a significant amount of discussion in this mathematical textbook. To a remarkable degree, cosmic sections were associated with hexameral themes and interpretation. The same is true of global sections and views in Theories of the Earth.

[120]Beati echoed the originally Stoic metaphor—endorsed by Bellarmine but rejected by Clavius—that planets move through the fluid heaven as birds fly through the air or as fishes swim through the sea. Also, Beati pointed out that the supralunar motions of comets could not be understood if the planetary heaven were solid. Beati, 111-112. On Bellarmine's inability to explain the motion of the fixed stars see footnote 106 on page 419. Cf. Riccioli, *Almagestvm Novvm,* 224 and 244.

[121]Beati, 113.

§ 6-iii. Hexameral Idiom and Non-Aristotelian Discourse

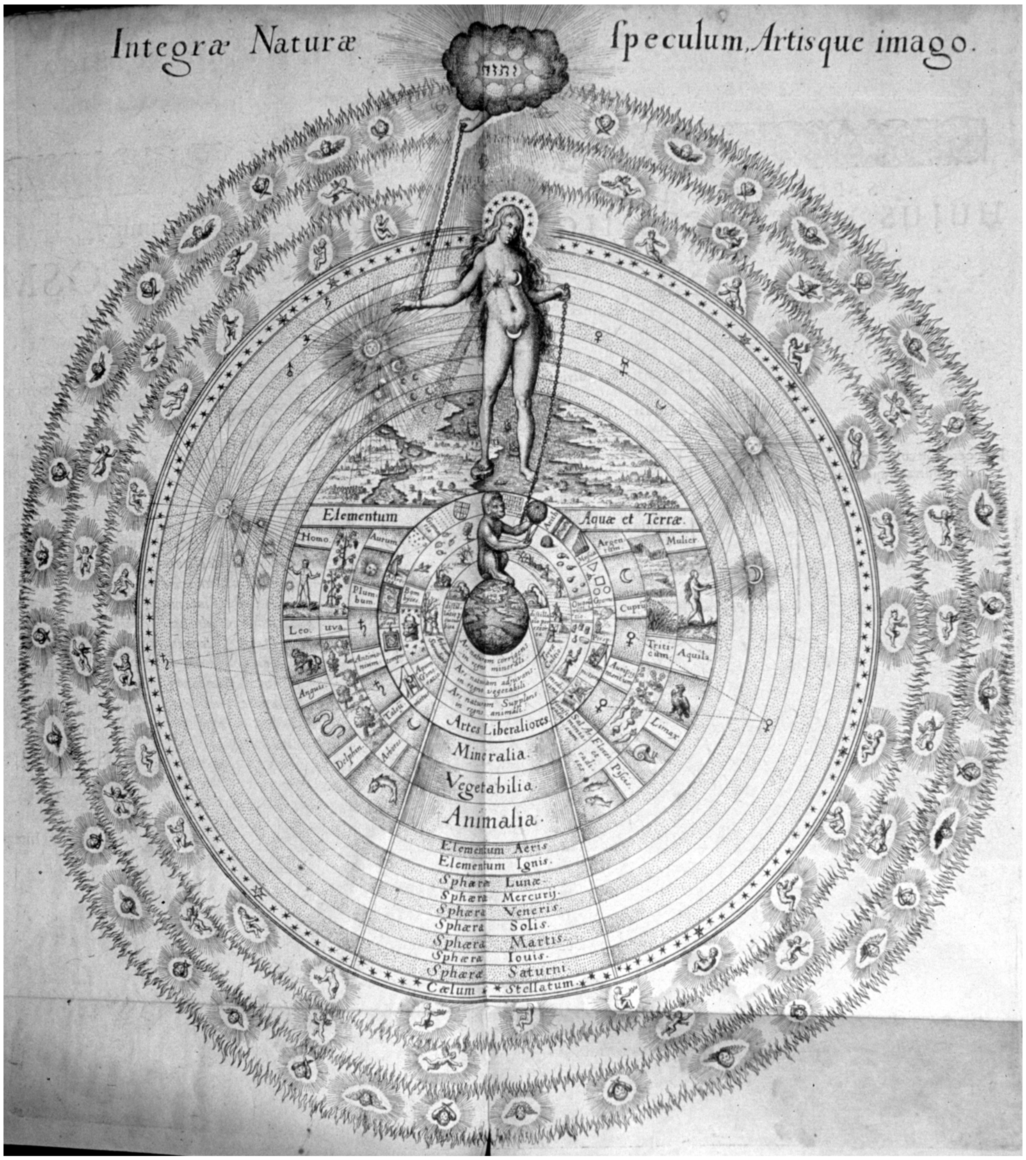


FIGURE 75. Robert Fludd, Integra natura. 1617. LH.

Contemporary with Tycho, various sorts of chymical cosmologies developed associated with the followers of Paracelsus. A variety of what may loosely be called Paracelsian cosmic sections, such as Robert Fludd's "Integrae natura" (Figure 75), occur throughout the seventeenth century featuring emblematic figures, hermetic signs, and Neoplatonic or mystical motifs relating to the great chain of nature.[122] Similar cosmic sections appear, for example, in Johann Mylius, *Opus Medico-Chymii* (1618), and Tobias Schütz, *Harmonia macrocosmi cum microcosmi* (1654).[123] In the latter the cosmic section is framed by cameos of Hermes Trismegistes and Paracelsus.

Although it lacks the emblematic features, the global section of Johann Joachim Becher (1635–1682) shows how hexameral idiom pervaded the writings of the Paracelsian, or better, chymical philosophers, who frequently regarded their art as a reproduction or imitation of the alchemical processes first used by the Creator during the creation week.[124] Becher produced a mineralogical tour of the subterranean world in his *Physica subterranea* (1668).[125] For Becher the chemical laboratory provided a scene for the re-enactment of processes which occur in the subterranean laboratory of nature. Like chymical cosmogonists before him from Paracelsus to van Helmont, Becher believed that God created the solid Earth from an original fluid chaos as described in the first book of Genesis, through chymical processes of precipitation and crystal-

[122]Robert Fludd is discussed below; See "Baptizing Descartes," page 453. On iconic and emblematic representations in early modern scientific works cf. William B. Ashworth, Jr., "Light of Reason, Light of Nature: Catholic and Protestant Metaphors of Scientific Knowledge," *Science in Context*, 1989, 3: 89–107; and idem, "Natural History and the Emblematic World View," in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert S. Westman, 303–32 (Cambridge: University of Cambridge Press, 1990).

[123]The cosmic section of Mylius is reproduced in Whitfield, *Landmarks,* 102; that of Schütz in Allen G. Debus, *Man and Nature in the Renaissance,* Cambridge History of Science Series (Cambridge: Cambridge University Press, 1978), 28.

[124]Because much of seventeenth-century chemistry appears to the modern reader neither as chemistry nor alchemy as they are usually understood, scholars such as Lawrence Principe and William Newman urge that historians adopt the word chymistry, an actors' category. Becher provides one example of the labyrinthine entanglement of chemistry and alchemy.

[125]Johann Joachim Becher, *Centrum Mundi Concatenatum, Seu Duum Viratus Hermeticus, Sive Magnorum Mundi Duorum Productorum Nitri & Salis Textura & Anatomia, Aeris nempè & Maris Consideratio. Pro Commentario in Posterior Duo Capita Supplementi Primi Physicæ Suæ Subterraneæ* (Norimbergæ & Altorfii, Apud Hæredes Johann. Danielis Tauberi, 1719). On Becher see Allen G. Debus, *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries*, 2 vols. (New York: Science History Publications, 1977); Norma Emerton, *The Scientific Reinterpretation of Form* (Ithaca: Cornell University Press, 1984); Norma E. Emerton, "Creation in the thought of J.B. Van Helmont and Robert Fludd," in *Alchemy and chemistry in the 16th and 17th centuries,* ed. Antonio Clericuzio Piyo Rattansi, 85–101 (Dordrecht: Kluwer Academic, 1994); David Oldroyd, "Some Neoplatonic and Stoic Influences on Mineralogy in the Sixteenth and Seventeenth Centuries," *Ambix*, 1974, 21: 128–156; and David Oldroyd, "Some Phlogistonic Mineralogical Schemes, Illustrative of the Evolution of the Concept of 'earth' in the Seventeenth and Eighteenth Centuries," *Annals of Science*, 1974, 31: 269–305.

lization.[126] Johan van Helmont argued that water, formed on first day, is the primary element which became transformed into everything else.[127] Robert Boyle critiqued chymical cosmogonies in his *Sceptical Chymist* (1661), and disagreed with the conclusions van Helmont drew from his willow-tree experiment.[128] Becher similarly disagreed with van Helmont regarding the primacy of water; rather, for Becher minerals were generated from both earth and water.

Becher's mineralogical geogony is illustrated with a striking global section of the laboratory of the Earth (Figure 76). The section features a central fiery region fueled by surrounding sulphurous and bituminous matter. Ocean water penetrates through deep fissures down into this fiery center, producing great quantities of pressurized steam which contributes to the central fiery chaos. Exhalations from this central chaos eventually make their way through other fissures to the surface of the continents, appearing as springs or condensing as metals in the fissures of the rocks.

[126] Paracelsus argued that his three principles of salt, sulfur and mercury provided a chymical key to understanding the universe. Heinrich Khunrath (1560-1605) "beheld in his fantasy the whole cosmos as a work of Supernal Alchemy, performed in the crucible of God." The *New Light on Alchymie* (1650) of Michael Sendivogius (1556-1636) and the *Basilica Chymica* (1609) of Ostwald Croll explained Genesis 1 as a chymical allegory. The *Secrets Reveal'd* of Eirenaeus Philalethes (George Starkey) purported to show how alchemy retraces the creation (and was studied by Boyle and Newton). For hexameral idiom in seventeenth century chymical cosmogony see the work of Debus; e.g., Allen G. Debus and Michael T. Walton, eds., *Reading the Book of Nature: The Other Side of the Scientific Revolution*, Sixteenth Century Essays & Studies, no. 41 (Kirksville, Missouri: Thomas Jefferson University Press and Sixteenth Century Journal Publishers, 1998).

[127] In a quantitative experiment Helmont grew a willow tree for 5 years. At the end of the five years the tree had drastically gained in weight while the earth in which it grew lost only a trifle; therefore, Helmont reasoned, the bulk of the tree must have sprung from water. *Ortus Medicinae*, 1648. *Oriatricke or Physick Refined*. Cf. Charles Webster, "Water as the Ultimate Principle of Nature: The Background to Boyle's *Sceptical Chymist*," *Ambix* 13 (1966): 98–105.

[128] Robert Boyle, *The Sceptical Chymist* (New York: E. P. Dutton and Company, 1949), 71-76. The beginning section of Part II is concerned with refuting claims that the Paracelsian *tria prima* were actually fundamental.

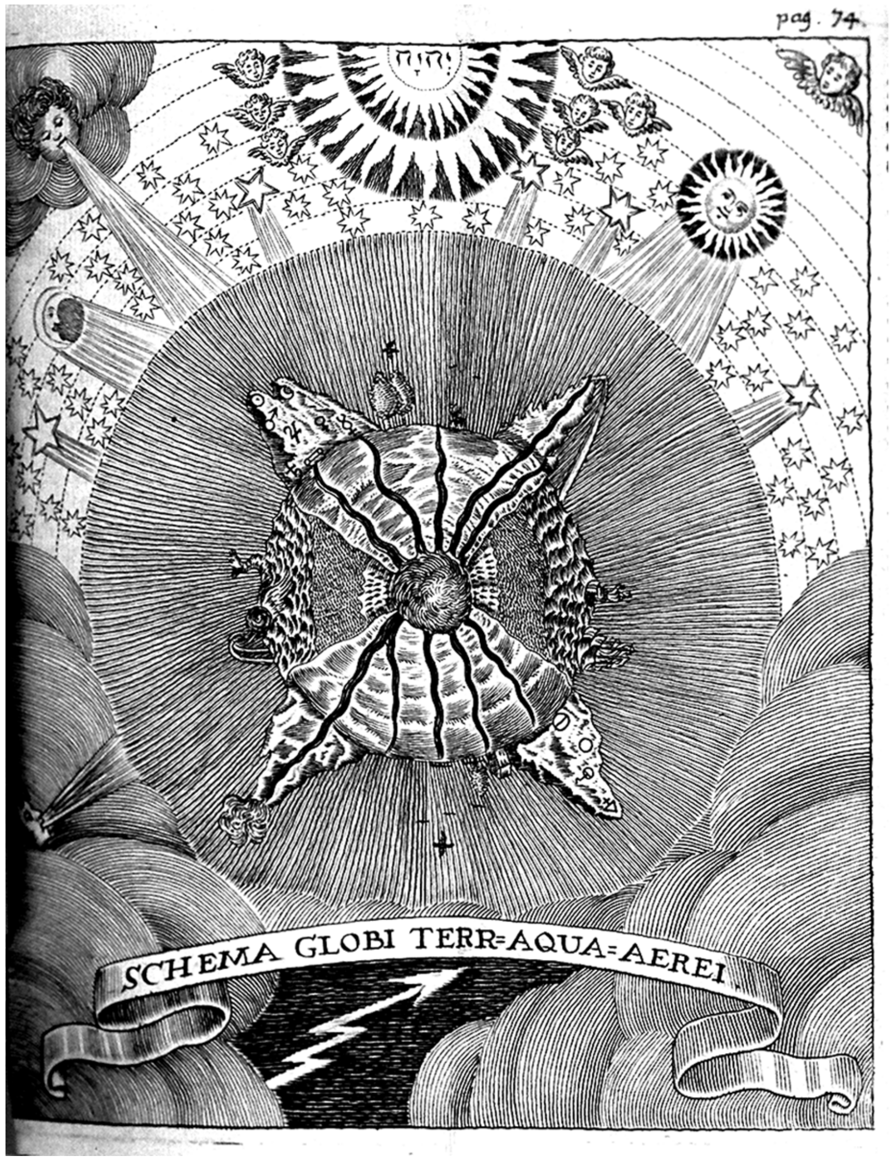


FIGURE 76. *Schema mundi*, Becher's mineralogical global section.

Although the hexameral literature was often synthetic and contested, sometimes largely encyclopedic and eclectic in character, as a common repository of opinions on natural topics it could inculcate or reinforce selected aspects of Aristotelian, Stoic, or Neoplatonic views. This is not to say that the hexameral literature was the only or even the chief source of transmission of these views, or the motivation for holding some of them, or that it propagated any system in a philosophically coherent and systematic form, but it was significant in legitimizing and disseminating certain views and in disposing its readers toward approving them and developing them in particular directions. For example, theologians like Bellarmine and cosmologists like Beati saw in the hexameral account evidence that, to them, undermined the Ptolemaic-Aristotelian world picture. The hexameron provided numerous opportunities to undermine Aristotelian cosmology, some of which are listed in Table 50.

TABLE 50. Anti-Aristotelian inferences sometimes drawn from the Hexameron

	Feature
a	Eternity of the World, Creation in an instant, or a Succession of days? The Augustinian exegesis that the heavens and the Earth were created in an instant was displaced by humanist scholarship with a literal interpretation of a succession of days. The emphasis on a succession of days was often accompanied by rhetoric against Aristotelian views of the eternity of the world.
b	Unity of the heavens and the Earth
c	Time existed before the heavens, since the Sun, Moon and stars are not mentioned until the fourth day
d	A chaos, from which all things developed, existed before there was a habitable surface of the Earth.
e	Waters once covered the entire surface of the Earth, before they were gathered together to form the oceans and dry land on the third day.
f	Water exists above the firmament, not merely in the sublunar region.
g	Seminal reasons consistent with “Let the land produce....”
h	Failure of the heavens to play a necessary governing role in the natural order of the terrestrial realm.
i	Earth-privileging idiom

Textual traditions were prerequisite for adequate reception and dissemination of new knowledge. This entails neither continuity nor revolution, but (to borrow a Stoic idiom) interpenetration, with selective appropriation and various degrees of transformation. Cosmological systems from Ptolemy’s to Tycho’s to Descartes’ to Newton’s were developed with reference to hexameral discourse. Persuasive reconciliation of the hexameron with any cosmological system was tantamount to “Assimilation” according to Sabra’s model.[129] Hexameral idiom, like Theories of the Earth and global illustrations, comprised a mult-contextual discourse, widely respected as a potential source of relevant propositions and data embedded in an authoritative textual framework. Theoretical deliberations were at times shaped at a constitutive level by the appropriation of rhetorical forms arising from hermeneutical engagement with the text. As we shall see, the hexameral tradition profoundly affected early modern natural philosophers' sense of the Earth's past by providing Theorists of the Earth with a variety of conceptual resources that were appropriated into their historical sensibilities about the Earth.

[129]See "Appropriation Model: An Alternative to Marginality," beginning on page 341.

CHAPTER 5 Textual Assimilation: The Sacred Theory of Burnet

§ 1. Burnet's Circle of Time

Theories of the Earth take their name from the ambitious and highly literate work of the English scholar Thomas Burnet (ca. 1635–1715).[1] Burnet, physician to Charles II and later chaplain to William III, published his *Telluris Theoria Sacra* in 1681. Burnet's *Theory of the Earth* (as the English translation of 1684–90 was called) proved

[1] Although he adapted the phrase from Descartes, Burnet's work effectively established the scope of the tradition and made "Theory of the Earth" a popular way of referring to it. Critics frequently referred to Burnet simply as "the Theorist" (cf. page 100). The extent to which Burnet transformed this phrase from its Cartesian provenance is assessed in the conclusion to this chapter. For Burnet's biography see the *Life of Burnet* bound with Burnet's later *Archaeologiae Philosophicae: sive Doctrina antiqua de rerum originibus* (London: Typis R.N., Impensis Gualt. Kettilby, 1692). General studies of Burnet's Theory of the Earth and the controversies surrounding it include Michael Macklem, *The Anatomy of the World: Relations between Natural and Moral Law from Donne to Pope* (Minneapolis: University of Minnesota Press, 1958); Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca: Cornell University Press, 1959); and David Charles Kubrin, "Providence and the Mechanical Philosophy: The Creation and Dissolution of the World in Newtonian Thought. A Study of the Relations of Science and Religion in Seventeenth Century England" (Ph.D. dissertation, Cornell University, 1968).

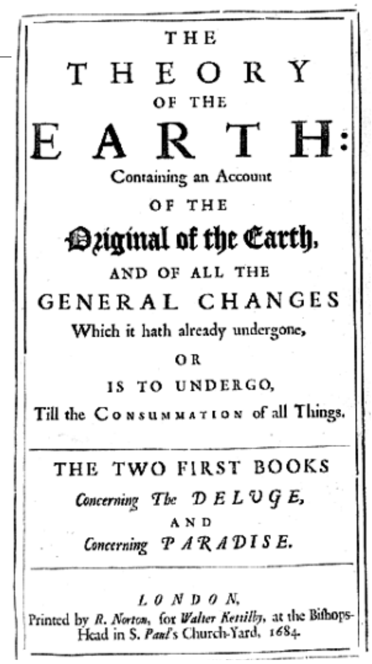
immensely popular, if the number of published editions is any indication (Table 51).[2] The number of writers over the next century who singled out Burnet as a target or foil for airing their own views confirms its immense influence in constituting a recognized tradition of debate. Although no single Theory of the Earth may be regarded as typical of all others, Burnet's work remains a paramount exemplar of the tradition, and as such its spectacular, carefully-orchestrated visual representations are worth examining in some detail.[3]

TABLE 51. Editions of Telluris Theoria Sacra

Year	Place	Lang.	Books	Notes	Location[a]
1681	London	Latin	I, II	1st ed.	HSCI, LH
1684	London	English	I, II	1st English ed.	HSCI, LH
1688	London	Latin	III, IV	1st ed. of last two books	HSCI, LH
1689	London	Latin	I, II	2d ed., bound with 1688	HSCI, LH
1690	London	English	III, IV	1st English ed. of last two books	HSCI, LH
1691	London	English	I, II	Bound with 1690	HSCI, LH
1697	London	English	I, II, III, IV	3d ed.	HSCI, LH
1699	Amsterdam	Latin	I, II, III, IV		HSCI, LH
1702	London	Latin	I, II, III, IV	3d ed.	HSCI, LH
1703	Hamburg	German	I, II, III, IV		HSCI
1726	London	English	I, II, III, IV	6th ed.	HSCI, LH
[1734]	London	English	I, II, III, IV		LH
1759	London	English	I, II, III, IV	7th ed.	HSCI
1816	London	English	abridged	Different frontispiece	HSCI
1965	Carbondale	English	I, II, III, IV	Rpt. 1690-91 ed.	

a. "HSCI" refers to volumes held in the History of Science Collections of the University of Oklahoma; "LH" refers to the Linda Hall Library, Kansas City, Missouri.

2 Burnet became chaplain to William III in 1692, a decade after publication of the first two books of his Theory treating the deluge and paradise in Latin in 1681: Thomas Burnet, *Telluris Theoria Sacra: Orbis Nostri Originem & Mutationes Generales, quas Aut jam subiit, aut olim subiturus est, Complectens. Libri duo priores de Diluvio & Paradiso* (London: Typis R. N.; Impensis Gault. Kettilby, 1681). An English edition of the first two books was published in 1684, dedicated to Charles II. At this time Burnet served as Charles II's physician. In 1690 a second edition in four books, including two new books on the future conflagration of the world and the millennium, was published in both Latin and English. Subsequent editions and translations identified in the table are listed in the bibliography. Unless noted otherwise, all citations to Burnet below will be to a modern reprint, Thomas Burnet, *The Sacred Theory of the Earth*, with an Introduction by Basil Wiley, including all four books from the 1690-91 edition plus *A Review of the Theory of the Earth*, 1690 (Carbondale: Southern Illinois University Press, 1965); hereafter simply "Burnet."



THE
THEORY
OF THE
EARTH:
Containing an Account
OF THE
Original of the Earth,
AND OF ALL THE
GENERAL CHANGES
Which it hath already undergone,
OR
IS TO UNDERGO,
Till the CONSUMMATION of all Things.

THE TWO FIRST BOOKS
Concerning The DELUGE,
AND
Concerning PARADISE.

LONDON,
Printed by *R. Norton*, for *Walter Kettilby*, at the Bishops-Head in S. *Paul's* Church-Yard, 1684.

FIGURE 77. Thomas Burnet, *Theory of the Earth* (1684). Title page of first English edition. HSCI.

The long title of a 1690 edition indicates the comprehensive temporal scope of Earth history—past, present, and future—encompassed by Burnet's Theory:

> The Theory of the Earth: Containing an Account of the Original of the Earth, and of all the General Changes Which it hath already undergone, or is to undergo, Till the Consummation of all Things. The Two First Books, Concerning The Deluge, and Concerning Paradise. The Two Last Books, Concerning the Burning of the World, and Concerning the New Heavens and the New Earth.

The work's bold design ("all the General Changes") and epic sweep (from creation to consummation) are apparent from Burnet's opening words:

> This Theory of the Earth may be call'd Sacred, because it is not the common Physiology of the Earth, or of the Bodies that compose it, but respects only the great Turns of Fate, and the Revolutions of our Natural World; such as are taken notice of in the Sacred Writings, and are truly the Hinges upon which the Providence of this Earth moves; or whereby it opens and shuts the several successive Scenes whereof it is made up.[4]

The overlap of Earth history with biblical history in Burnet's conception was quite intentional, and reflects no modest agenda. On the heels of Milton, few English scholars felt constrained to write sacred history only for divines. It was an age with a serious and intense appetite for Sacred Geographies and Universal Chronologies, all of which with the best of humanist scholarship promised to integrate modern discoveries with biblical, classical and other learning, for the defense of religion and the consternation of various scoffers, wits, deists

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3 David Kubrin and Stephen Jay Gould have previously described Burnet's illustrations, although with different emphases than mine. See Kubrin, "Providence and the Mechanical Philosophy," chapter 5; and Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge: Harvard University Press, 1987), chapter 2.

4 Burnet, 15.

or atheists.[5] That Burnet would employ Sacred History to identify the "great Turns of Fate, and the Revolutions of our Natural World" involved in shaping the "successive Scenes" of the globe reflects, given an avowed allegiance to the established social order, the ambitious extent of his epic design.

The "several successive Scenes" in the history of the globe were depicted in the striking frontispiece to the Theory (Figure 78). This visual representation is so effective a summary of Burnet's Theory that his views often are described simply by reference to this engraving.[6] It is at once apparent that Burnet's Theory of the Earth bears little resemblance to a work of geology, other than the fact that it deals with the Earth as its subject matter (cf. the epigraph for Part II). Understandably, for many modern geologists Burnet's Theory cannot even count as proto-geology—there is no mention of fossils, no hint of stratigraphy, and no use of fieldwork

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5 Examples of sacred geographies include Samuel Bochart, *Geographia Sacra* (1646) and Edward Stillingfleet, *Origines Sacrae, a Rational Account of the Grounds of Natural and Reveal'd Religion* (London, 1662); for brief summaries of these works see Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries* (New York: Columbia University Press, 1934; reprinted New York: Octagon Books, 1968), chapter 6, and David N. Livingstone, *The Geographical Tradition: Episodes in the History of a Contested Enterprise* (Boston: Blackwell Scientific Publications, 1992). Examples of sacred chronologies include Isaac Voss, *Castigationes ad Scriptum Georgii Hornii De Aetate Mundi* (The Hague: Ex typographia Adriani Vlacq, 1659), and Georg Horn, *Dissertatio de vera Aetate Mundi: qua Sententia illorum refellitur qui statuunt Natale Mundi tempus Annis minimum 1440. vulgarem aeram anticipare* (Leiden: Apud Johannem Elzevirium & Petrum Leffen, 1659). A controversy ensued between Voss and Horn over chronological matters, after which the latter wrote a tract that may be regarded as a Theory of the Earth: Georg Horn, *Arca Mosis, sive Historia Mundi. Quae complectitur Primordia Rerum Naturalium omniumque artium ac scientiarum* (Leiden and Rotterdam: Ex officina Hackiana, 1668). Chronologies and seventeenth-century humanist scholarship are superbly analyzed by Anthony T. Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800* (Cambridge: Harvard University Press, 1991); see also John D. North, "Chronology and the Age of the World," in *Cosmology, History, and Theology*, ed. Wolfgang Yourgrau and Allen D. Beck, 307–333 (New York: Plenum Press, 1977). On scoffers, wits, et al., cf. Michael Hunter, *Science and Society in Restoration England* (Cambridge: Cambridge University Press, 1981); and Michael Hunter, "Science and Heterodoxy: An Early Modern Problem Reconsidered," in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert S. Westman, 437–460 (Cambridge: Cambridge University Press, 1990.

6 Although frequently redrawn, variations of the frontispiece are minor, including background hatching rays, additional cherubs, repositioned Greek lettering, redrawn global scenes, and alterations in the Christ figure and the banner. For an insightful analysis of the frontispiece which differs from mine in many details see Gould, *Time's Arrow*, chapter 2. At the beginning of this chapter Gould reprints the frontispiece from the 1688-1689 Latin edition, ambiguously labelled as a "first edition." Although this edition was not the first to include a frontispiece, it was the first edition to include all four books (combining the second edition of the first two books with the first edition of the last two books). The only differences between the 1688-1689 Latin frontispiece and the 1690 English frontispiece are minor repositioning of the words and the banner. Other than the first 1681 Latin edition, the only printing of Burnet's Theory published without this frontispiece of which I am aware is an early nineteenth-century collection of excerpts from the Theory which substituted a pastoral scene of Adam naming the animals; cf. Bishop [*sic*] Burnett [*sic*], *Sacred Theory of the Earth* (n.p., 1816). Thomas Burnet the Theorist should not be confused with his contemporaries Gilbert Burnet, Bishop of Salisbury, or Thomas Burnett, a friend of John Locke.

undertaken by either himself or others. In contrast, the work is learned and literary; destined to be regarded by its detractors as a captivating "romance" rather than sober natural knowledge. Yet Burnet regarded it as a serious scientific updating of outmoded Aristotelian views. The new scientific perspective was largely Cartesian rather than scholastic. Burnet offered a grand cosmic history such as Milton's, retaining all the drama while losing only the meter in the course of being made more faithful to the truth.[7] As will become clear from the frontispiece itself, Burnet's Theory of the Earth consisted of almost equal parts Cartesian cosmology, apocalyptic theology and classical learning, integrated in a matrix of Cambridge Platonism—or, as he might have said, Reason, Scripture, and Antiquity integrated in a most orderly and regular fashion.

[7] Some later editions did not even dispense altogether with meter, adding an "Ode to Burnet" by Joseph Addison: "How strong each Line, each Thought how great; | With what Energy you rise! | How shines each Fancy? with what Heat | Does every glowing Page surprize?" (Quoted from the 1726 edition.) It became a commonplace for critics to dismiss Burnet's Theory as well-written literature, composed with poetic license, rather than a serious contribution to natural philosophy (cf. Keill's criticism on page 324). However, Burnet insisted his Theory was not a poem or a philosophic romance. Speaking of critics' lack of capacity for theoretical reflection, he wrote: "I mean Men of Wit and Parts, but of short Thoughts, and little Meditation, and that are apt to distrust every thing for a Fancy or Fiction that is not the dictate of Sense, or made out immediately to their Senses. Men of this Humour and Character call such Theories as these, Philosophick Romances, and think themselves witty in the expression; They allow them to be pretty amusements of the Mind, but without Truth or reality. I am afraid if an Angel should write the Theory of the Earth, they would pass the same judgment upon it; Where there is variety of Parts in a due Contexture, with something of surprising aptness in the harmony and correspondency of them, this they call a Romance; but such Romances must all Theories of Nature, and of Providence be, and must have every part of that Character with advantage, if they be well represented. There is in them, as I may so say, a Plot or Mystery pursued through the whole Work, and certain Grand Issues or Events upon which the rest depend, or to which they are subordinate; but these things we do not make or contrive our selves, but find and discover them, being made already by the Great Author and Governour of the Universe: And when they are clearly discover'd, well digested, and well reason'd in every part, there is, methinks, more of beauty in such a Theory, at least a more masculine beauty, than in any Poem or Romance; And that solid truth that is at the bottom, gives a satisfaction to the Mind, that it can never have from any Fiction, how artificial soever it be." Burnet, 17.

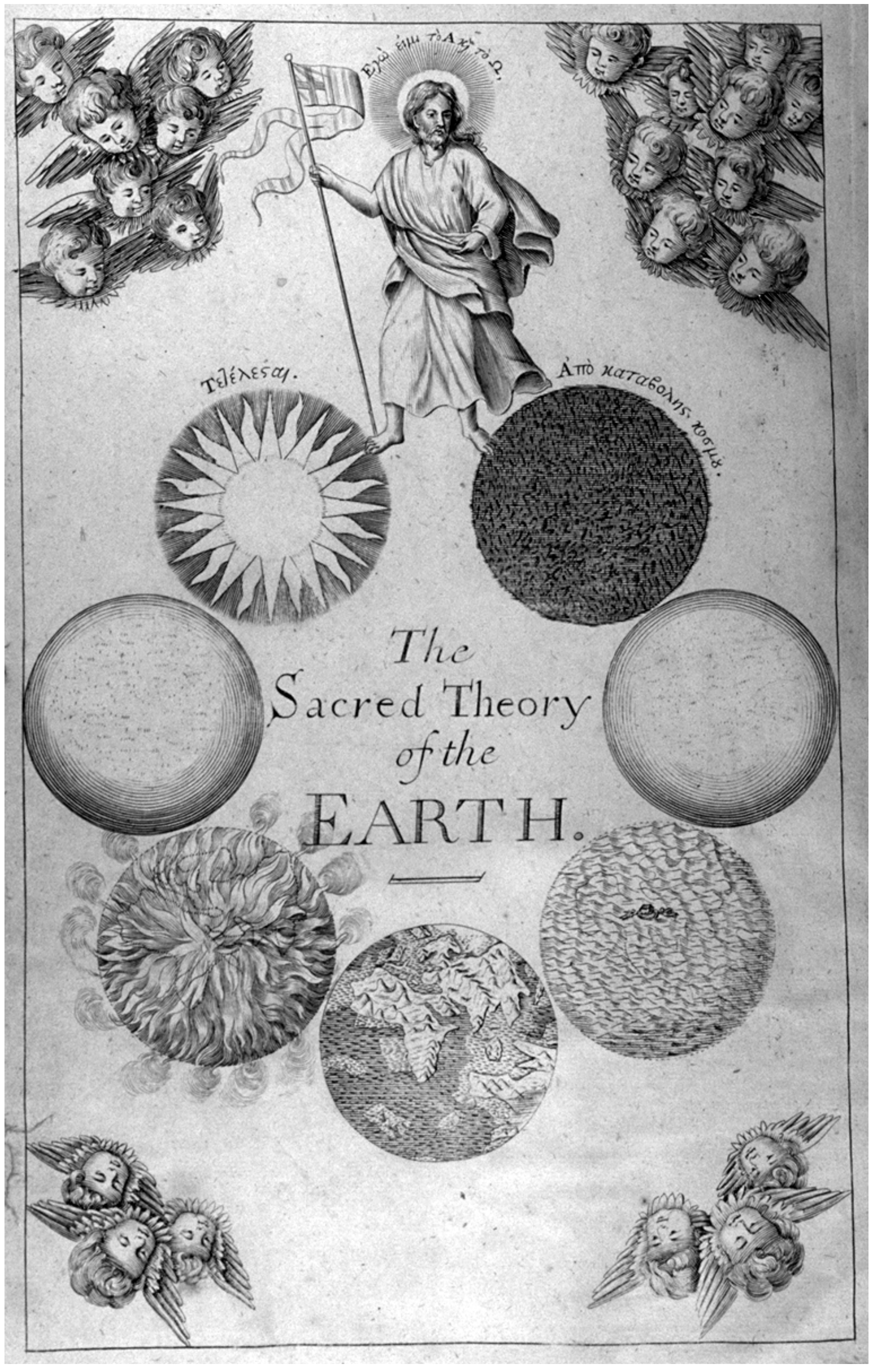

FIGURE 78. Thomas Burnet, *Theory of the Earth* (London, 1684). HSCI.

Description. Original version of Burnet's frontispiece. The frontispiece was not prepared for the 1681 Latin edition of the two first books, but first appears in the 1684 English translation. Once created it became very durable, and thereafter various versions of it adorned all early editions of Burnet's work.

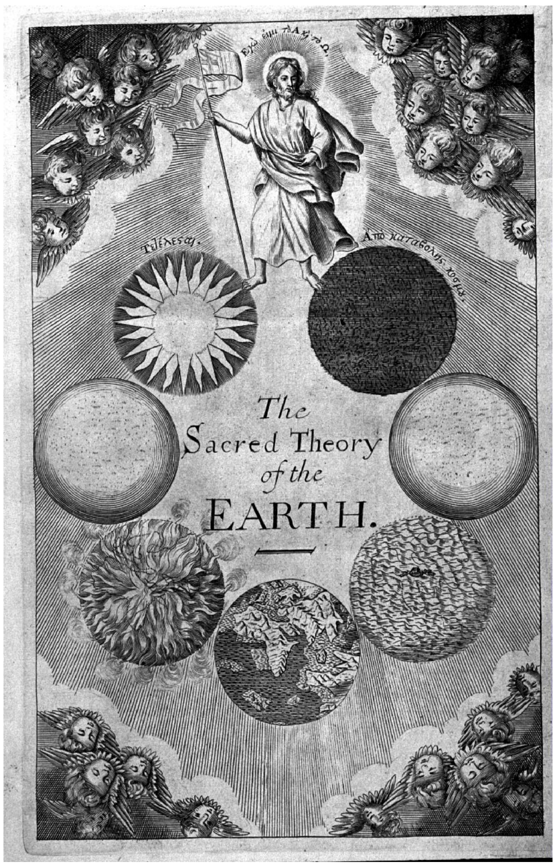

FIGURE 79. Thomas Burnet, *Theory of the Earth* (London, 1690). HSCI.

Description. This frontispiece to the first complete edition of all four books of the Theory is identical in all respects to the original frontispiece except for the addition of rays and of extra cherubs.

FIGURE 80. Thomas Burnet, *Theoria Sacra Telluris* (Hamburg, 1703). HSCI.

Description. This German-language text sports a German title in the frontispiece (unlike the Latin title on the title page). Perhaps the most obvious of the minor changes in this version of the frontispiece is a diminished circularity.

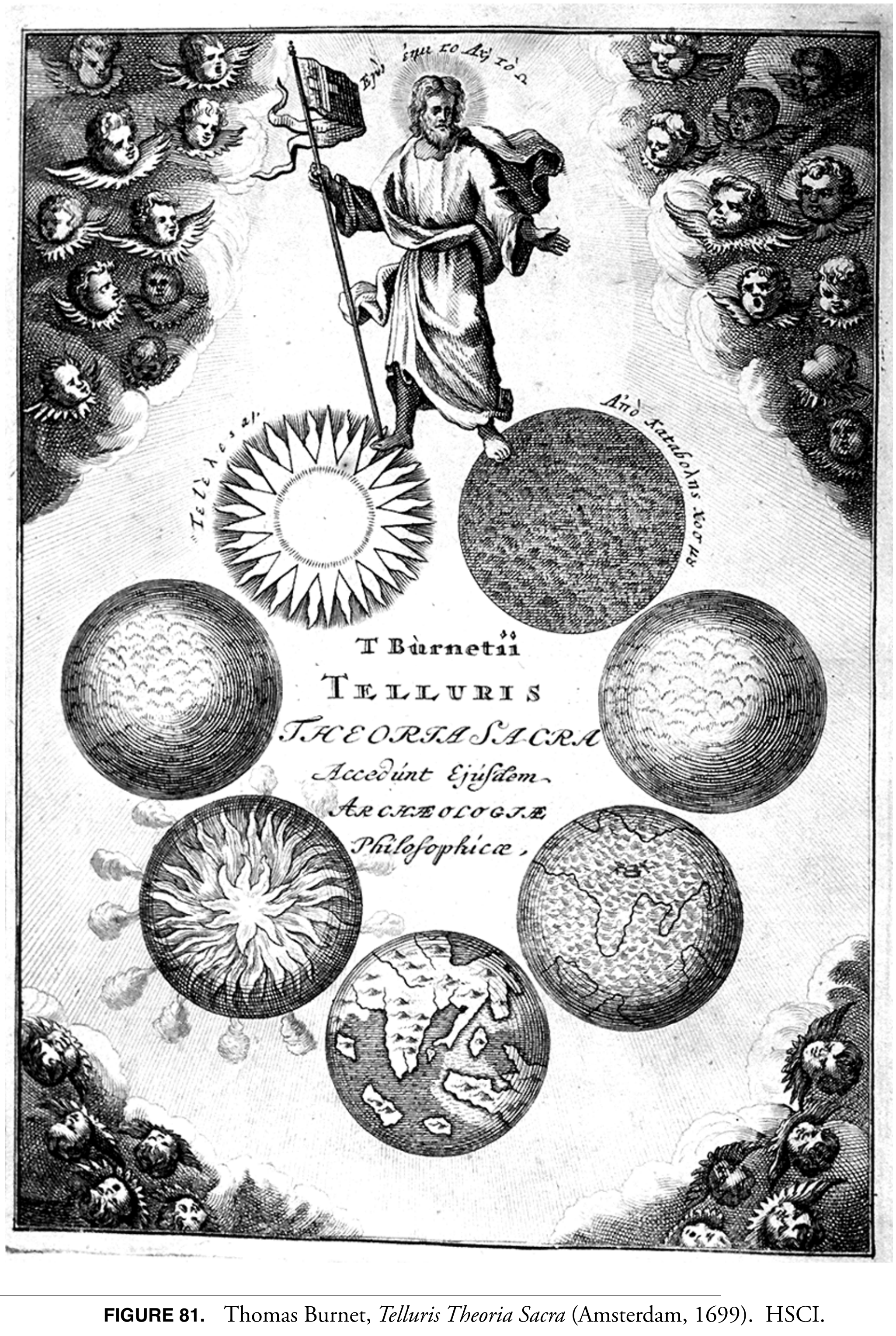

FIGURE 81. Thomas Burnet, *Telluris Theoria Sacra* (Amsterdam, 1699). HSCI.

§ 2. Scripture and Apocalyptic Theology

Although his explicit biblicism would not endear Burnet to later geologists, the scriptural connotations of his theory were part of the idiom in which he lived and moved and had his being. Even a casual glance reveals that undisguised biblical motifs are prominently displayed in the frontispiece, presumably exerting a powerful influence upon his contemporary audience despite the difficulties a modern viewer may experience trying to resurrect a similar sense of their rhetorical vitality. That Burnet's Theory is frequently called *The Sacred Theory of the Earth* owes something to the frontispiece. The title pages of all English editions published in Burnet's lifetime refer to the work simply as *The Theory of the Earth* (which did not carry religious connotations), omitting the word "Sacred." In each case it is the frontispiece that explicitly adds the adjective "Sacred," both verbally in the central title and nonverbally through the biblical motifs the frontispiece invokes.[8]

Above the scenes of globes a robed figure spans the beginning and the end of Earth history. Over his head is written "I am the Alpha and the Omega;" or, to complete the quotation attributed to Christ in the *Book of Revelation*, "the beginning and the end, the first and the last."[9] The figure is neither inert nor unbalanced, but dynamic and active. Foreseeing all at the beginning of Earth history, his torso is oriented to receive all things returning to him at the

[8] See the 1684, 1690, 1691, and 1697 English editions. In no case is the adjective "Sacred" found on the title page of these earliest English editions, but *Sacra* or "Sacred" is included in the frontispiece in all seventeenth-century English and Latin editions. This point should not be overstressed; I am not implying that Burnet was disguising his attempt to secure biblical sanction for his Theory. After all, the Latin title was *Telluris Theoria Sacra*, and all title pages in any language give the contents of the separate books which carried explicit biblical references. Lest there be any doubt, Burnet explained why his Theory should be considered a "Sacred Theory" on the very first page of the English editions, as quoted above. So the appeal to biblical motifs was a central aspect of Burnet's Theory, both substantively and rhetorically considered. But surely it is of interest that it was in the midst of the visual rhetoric of the frontispiece that Burnet explicitly entitled his Theory as Sacred, and that the title of the frontispiece should have become the usual way of referring to his work. The 1726 English edition is the first I have seen to add "Sacred" to the titlepage in small lettering at the top. The 1965 reprint of the 1690 edition uses the frontispiece title rather than *The Theory of the Earth* as on the 1690 title page.

[9] Revelation 22:13 KJV.

end.[10] All compositional elements, even the distant scenes of the Earth, are linked by lines of radiance converging in him.[11]

Christ's left foot rests upon a ball of chaos, a globe "without form and void," under the caption Ἀπο Καταβολης Κοσμου, "From the Foundation of the World."[12] This biblical idiom recalls the creation but also resonates with apocalyptic overtones, as do similar phrases such as απ̓ αρχης κτισεως, "from the beginning of the creation."[13] The latter phrase appears in one of the most quoted passages in the New Testament regarding the history of the Earth, 2 Peter 3: 3–13, which in all likelihood is the primary allusion behind Burnet's caption.[14] After an entire chapter replete with warnings about false teachers that will arise in the last days, the epistle of 2 Peter admonished:

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[10] One cannot but think of the cyclic pattern of Thomas' *Summa theologiae* which, after beginning with God himself, continues with the initial procession of all creatures from God, followed by the creaturely ascent returning to God.

[11] The first English edition in 1684 uses hatching only to represent a halo around the Christ figure against a white background. The rays of hatching first appear in the Latin edition of 1688-89 and the English editions of 1690 and 1691. Background hatching is included in all later versions, with minor variations (e.g., it is extremely light in the 1699 Latin edition).

[12] After several chapters recording Christ's last words spoken to comfort his disciples in the week before his death, John 17: 24 refers to the pre-incarnate glory of Christ as revealed both in creation and at the end of time: "Father, I will that they also, whom thou hast giuen me, be with me where I am, that they may behold my glory... for thou louedst mee before the foundation of the world." Including this verse, there are ten New Testament references either to *Apo Kataboles Kosmou* or *Pro Kataboles Kosmou*: Matthew 13:35; Matthew 25:34; Luke 11:50; John 17:24; Ephesians 1:4; Hebrews 4:3; Hebrews 9:26; 1 Peter 1:20; Revelation 13:8; Revelation 17:8. I thank Prof. Mack Roarck, personal communication, for paleographical assistance with this caption and other lettering on the engraving, especially with the form of beta in *Kataboles* and the genitive noun ending of *Kosmou* where the upsilon is written above the omega in an omega-upsilon ligature. For similar examples, see B. A. Van Groningen, *Short Manual of Greek Palaeography*, 3d ed. (Leyden: A. W. Sythoff, 1963) and Bruce M. Metzger, *Manuscripts of the Greek Bible: An Introduction to Greek Palaeography* (Oxford: Oxford University Press, 1981).

[13] H. H. Esser comments that *apo kataboles kosmou* was used by Polybius (2nd century B.C.) and Aristeas (before 100 B.C.) to refer to the historical starting point for the totality of created things. In reviewing its biblical usage Esser concludes: "Two points stand out in all the texts which mention the foundation of the world. One is that it is always associated with a statement about man's destiny. The other is the implied connection between God's foreknowledge and predestination.... [Christ] reveals in the midst of history what has been hidden since the foundation of the world, and thus fixes the end of time." Similarly, Esser suggests that the biblical use of *ktizo* (to create) "refers not only to God's activity in calling the world and individual creatures into being, but also to his actions in history which lie behind election, temporal destiny...." S.v. "Creation," vol. 1, pp. 376–379, *The New International Dictionary of New Testament Theology*, ed. Colin Brown (Grand Rapids: Zondervan Publishing House, 1967), 3 vols.

[14] For other possibly relevant occurrences of this phrase, cf. Romans 1: 20 and Wisdom of Solomon 13: 5.

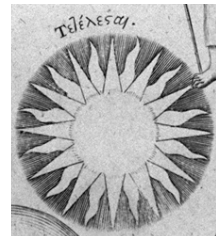
> Knowing this first, that there shall come in the last days scoffers, walking after their own lusts. And saying, Where is the promise of his coming? for since the fathers fell asleep, all things continue as they were *from the beginning of the creation*. For this they willingly are ignorant of, that by the word of God, the heavens were of old, and the earth consisting of water and by water. Whereby *the world that then was*, being overflowed with water, perished. But *the heavens and the earth that are now*, by the same word, are kept in store, reserved unto fire against the day of judgment, and perdition of ungodly men.... The day of the Lord will come as a thief in the night, in which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat; the earth also and the works that are therein shall be burnt up. Nevertheless we, according to his promise, look for new heavens and *a new earth*, wherein dwelleth righteousness.[15]

The translation above is as Burnet quoted it, affirming its "plain sence, according to the most easie and natural explication."[16] The "plain" and "easie" sense of this passage, as Burnet read it, spoke of three different worlds, the "world that then was"; the "earth that [is] now"; and "a new earth" that is to come. For Burnet, Peter was of greater importance than Moses for deciphering the "whole Circle of Time and Providence." Burnet repeatedly invoked this passage to deflect criticisms raised on the basis of Genesis and to justify his Theory as a literally-true Petrine philosophy of the Earth.[17]

[15] The King James Version as quoted by Thomas Burnet, *A Review of the Theory of the Earth, And of its Proofs: Especially in Reference to Scripture* (London: Printed by R. Norton, for Walter Kettilby, at the Bishop's Head in St. Paul's Church-Yard, 1690). Reprinted in Burnet, 386. Italics added. Burnet has emended the KJV "standing out of" to "consisting of" in verse 5, in accordance with the Vulgate *consistens*. "Standing out of" was often interpreted as referring to the separation of the dry land and the sea in the creation week, which was impossible for Burnet's Theory to accommodate. Burnet devoted a long paragraph in the 1681 edition to a grammatical examination of the Greek text for the *consistens* phrase; Burnet (1681), 200-201. Compare the criticism of Bishop Croft in footnote 136 on page 497.

[16] Burnet, 386.

[17] The quoted phrase is found in Burnet, 24. Cf. Burnet, *A Review of the Theory of the Earth*, 385: "The Sacred Basis upon which the whole Theory stands, is the doctrine of St. Peter, deliver'd in his Second Epistle and Third Chapter, concerning the Triple Order and Succession of the Heavens and the Earth. That comprehends the whole extent of our Theory: which indeed is but a large Commentary upon St. Peter's Text." For Burnet's reluctance to discuss the *hexameron*, or work of the six days of creation, see "The Idiosyncrasy of Burnet," beginning on page 496.



Christ's right foot is placed upon a transformed globe, depicted as a star at the final consummation of all things, under the caption Τετελεσαι, meaning "You have been perfected/completed/finished." It appears that Christ is depicted as declaring to the Earth that it has fulfilled its providential destiny in much the same way as he spoke of himself at the completion of his own earthly mission.[18] Once transfigured into a new star, with its inhabitants transported to Heaven, the former Earth will ascend to an exalted place among the fixed stars, perhaps becoming the habitation of angels or other spiritual beings: "This translation of the Earth... makes it leave its place, and, with a lofty flight, take its seat amongst the Stars."[19] Burnet believed in a plenitude of life throughout the universe. Fixed stars, he wrote, are

> always luminous, and always pure and serene. And if the worst and Planetary parts of [the Sun's] Dominions be replenisht with Inhabitants, we cannot suppose the better to lie as Desarts, uninjoy'd and uninhabited; his Subjects then must be numerous, as well as his Dominions large; And in both respects, this System of a Fixt Star, with its Planets (of which kind we may imagine innumerable in the Universe, besides this of the Sun, which is near and visible to us) is of a noble Character and Order, being the habitation of Angels and glorified Spirits, as well as of mortal Men.[20]

Christendom was traditionally represented by a sceptre which had one end shaped into a ball modeling the Earth, topped with a cross symbolizing the dominion of Christian kings. Here the banner of Christendom in Christ's hand designates him as King of Kings at the end of time. He stands not merely on one globe, but on a complete circle of seven globes in the eschatological fulfillment of the kingdom of God.[21] A more explicit visual declaration of orthodox Christology in a theoreti-

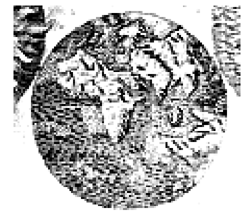
[18] *Tetelesai* does not occur in the New Testament. The stem *teleo* is found in the verse alluded to by the first caption, "I am the beginning and the end." *Tetelestai*, the third person singular perfect tense, most memorably occurs at John 19: 30 as the last saying of Jesus upon the cross: "It is finished." For identification of *Tetelesai* as the second person singular perfect tense of *teleo* (to complete, finish, end, accomplish), and particularly for help deciphering the script of the second tau and the alpha-iota ligature of *Tetelesai* as it is engraved on the frontispiece, I again thank Mack Roarck, personal communication.

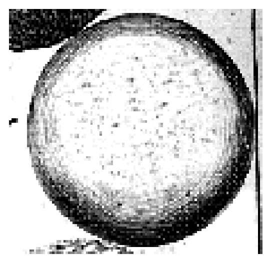
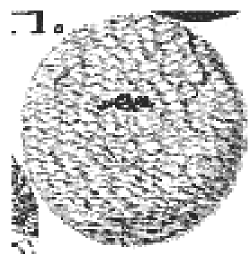
[19] Burnet, 377.

[20] Burnet, 225.

cal work on Earth history is hard to imagine. As original Creator and ultimate Ruler, in full view of cherubim longing to look into these things, Christ governs all scenes of global history from everlasting to everlasting, making the Earth his footstool.[22]

A globe depicting the Earth's present form and condition, located at the bottom of the engraving, features recognizable continents and oceans of the eastern hemisphere. Three scenes descend clockwise from the foundation of the world to the present:

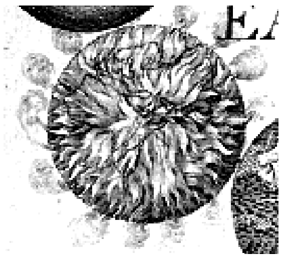
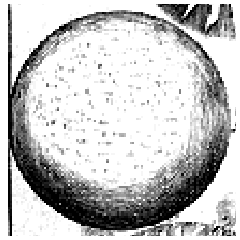
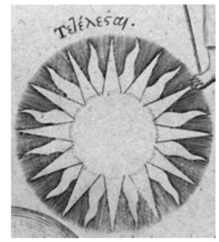


 The Original of the Earth in Chaos;	 Paradise;	 and the Deluge.

21 The number seven, of course, represented completeness, especially for Platonists from the time of Philo's commentaries on Genesis. In the Book of Revelation, the seven seals represent the secret plan of history opened by Christ (Burnet discusses these seals in Book IV, chapter IV, *passim*). There is a scene in the Book of Revelation where Christ stands in his temple among seven candlesticks. In esoteric literature the temple was frequently associated with the universe (Isaac Newton and Thomas Burnet both made this identification as well; see below). On visual representations of apocalyptic motifs, see Richard Kenneth Emmerson, *Antichrist in the Middle Ages: A Study of Medieval Apocalypticism, Art, and Literature* (Seattle: University of Washington Press, 1981).

22 Psalm 110, the well-known Messianic Psalm, provides relevant liturgical context in verse 1: "The Lord said unto my Lord: 'Sit thou at my right hand: until I make thine enemies thy footstool." The second Psalm, with its famous Messianic images, also evokes images of the rule of Christ over the Earth: "I shall give thee the heathen for thine inheritance, and the uttermost parts of the Earth for thy possession. You shalt break them with a rod of iron...." From Psalm 45 comes another reference: "Thy Throne, O God, is for ever and ever; The Scepter of thy kingdom is a right Scepter, etc." Burnet frequently cited these Psalms and other similar scriptures (e.g., Book IV, chapter V, *passim*).

Likewise, three scenes ascend clockwise from the present to the end of time:

		
The Conflagration or Burning of the World;	the New Heavens and the New Earth in the Millennium;	and the Consummation of all Things.

Burnet dedicated the English translation of his work to King Charles II with a verbal counterpart to the frontispiece, promising that his Theory would "connect the parts, and present them all under one view, that we may see, as in a Mirrour, the several faces of Nature, from First to Last, throughout all the Circle of Successions."[23]

This present Earth lies at the formal midpoint of the cycle of Earth history, as if the theater of the world were a play in seven acts.[24] However, the Earth is the midpoint by position, not necessarily by duration, for the scenes are of unequal length. As Burnet envisioned it, the present state of the Earth was the longest scene, having endured perhaps four thousand years

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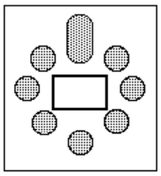
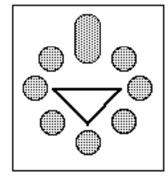
23 Burnet, 13. The mirror metaphor was a commonplace, evoking the encyclopedic "Mirror of the World" image, in which the entire compass of Nature would be reflected (e.g., Vincent of Beauvais, *Speculum Naturale*, 1624). The primary classical source of the phrase reinforces an image of circularity: the shields of Hercules (according to Hesiod) and Achilles (according to Homer, *Iliad* ch. 18) were microcosms of the world, depicting the habitable land (*orbis terrarum*) surrounded by the circular river of Ocean. Crates of Mallos referred to Achilles' shield as a *kosmou mimema* or image of the world, polished with a bright shine to reflect the macrocosm. See James S. Romm, *The Edges of the Earth in Ancient Thought: Geography, Exploration, and Fiction* (Princeton: Princeton University Press, 1992), 12–14.

24 Burnet frequently adopted commonplace stage metaphors in the *Theory of the Earth*, often in association with historical and apocalyptic motifs. With Abraham Ortelius' *Theatrum orbis terrarum* (1570); Jean Bodin's *Universae naturae theatrum* (1596), or the collection *Theatrum chemicum* (1602), this was one of the most common metaphors of the age; cf. Ann Blair, *The Theater of Nature: Jean Bodin and Renaissance Science* (Princeton: Princeton University Press, 1997), especially chapter 5, "Theatrical Metaphors." For a survey of apocalyptic dramatic traditions in sixteenth and seventeenth-century theater which provide an interesting context for these motifs see Frank Ardolino, *Apocalypse and Armada in Kyd's Spanish Tragedy*, Sixteenth Century Essays & Studies, ed. Charles G. Nauert, Jr., no. 29 (Kirksville, Missouri: Sixteenth Century Journal Publishers, 1995), esp. chapter 3; hereafter "Ardolino."

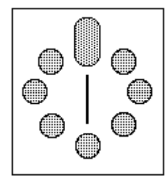
to his day. The chaos lasted an undisclosed length of time, presumably within the Creation Week; the antediluvian world existed a little more than 1600 years; the Deluge persisted for about one year; the conflagration will require about the same length as the watery chaos; and the Millennium or second Paradise perhaps a thousand years.[25]

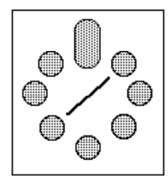


Thus four short-lived events arranged in a square (i.e., Chaos, Deluge, Conflagration, Consummation) frame a triangle of three longer-lasting stages: Paradise, the present Earth, and the Millennium; the three habitable worlds Burnet discerned in the second epistle of Peter.



The cycle's scenes are related by lines of correspondence along every axis: In a vertical correspondence, the present Earth at the midpoint of the cycle lies beneath the exalted Christ. At this lowest point in the divine comedy Christ entered the world for his scene of humiliation. "Earths are but the dirt and skum of the Creation, and all things were pure as they came at first out of the hands of God."[26] Rotating the line of correspondence one step clockwise, the starting scenes of each half cycle—the Original Chaos and the Burning Conflagration—are both chaotic predecessors of paradisiacal worlds:





> Wherefore if you would cast the Earth into a new and better mould, you must first melt it down; and the last Fire, being as a Refiner's fire, will make an improvement in it, both as to matter and form. To conclude, it must be reduc'd into a fluid Mass, in the nature of a Chaos, as it was at first; but this last will be a Fiery

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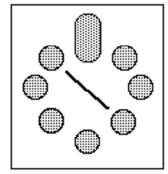
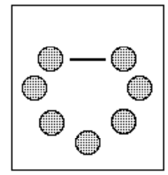
[25] Burnet, 26–27, 93. Burnet adopted the general chronological framework accepted by seventeenth-century English scholars, but in the *Theory* there remains an evasive ambiguity regarding the lengths of the creation week and of the millennium. The length of both the creation and millennium turned on the same hermeneutical issue; viz. that of distinguishing between literal and typological or allegorical senses of texts. "But when I speak of confirming this Doctrine [of the millennium] from other passages of Scripture, I do not mean as to that definite time of a thousand years, for that is no where else mention'd in the Apocalypse or in Scripture, that I know of; and seems to be mention'd here, in this close of all things, to mind us of that type that was propos'd in the beginning of all things, Of Six days and a Sabbath. Whereof each Day comprehends a thousand years, and the Sabbath, which is the Millennial state, hath its thousand." (Burnet, 334–335.) Burnet's hermeneutics, and the difficulties he encountered with the works of the six days, are surveyed in "The Idiosyncrasy of Burnet," beginning on page 496, as part of the assessment of the significance of the hexameral tradition for Theories of the Earth. See especially page 503.

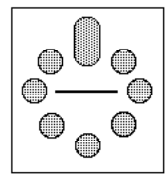
[26] Burnet, 225.

> Chaos, as that was Watery; and from this state it will emerge again into a Paradisiacal World.[27]

The third scenes in each half cycle—the Deluge and the Final Consummation—each bring an end to the preceding Paradisiacal world.

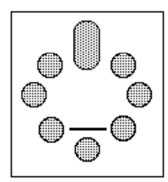






Further inspection of the engraving reveals a lateral symmetry, with corresponding scenes left and right. On the right side, the descent half of the cycle is watery; on the left side, the ascent follows the way of fire. The beginning and the end of Earth history are shown on either side at the top, “from a dark Chaos to a bright star.”[28] Along a horizontal axis midway on either side repose smooth, spherical, scenes of perfection: a Paradise lost...

> In this smooth Earth were the first Scenes of the World, and the first Generations of Mankind; it had the beauty of Youth and blooming Nature, fresh and fruitful, and not a wrinkle, scar or fracture in all its body; no Rocks nor Mountains, no hollow Caves, nor gaping Chanels, but even and uniform all over. And the smoothness of the Earth made the face of Heaven so too; the Air was calm and serene; none of those tumultuary motions and conflicts of vapours, which the Mountains and the Winds cause in ours: ‘Twas suited to a golden Age, and to the first innocency of Nature.[29]



And a Paradise regained. Nearest the present on either side at the bottom occur the great cataclysmic turns of fate: twin global destructions, first by water and then by fire.

By these axial and lateral correspondences the ascent half of the cycle repeats the descent even while superceding it. In summarizing the apocalyptic views of time of early modern commentators on the Book of Revelation, Frank Ardolino describes an his-

[27] Burnet, 288.

[28] Burnet, 377.

[29] Burnet, 64. Burnet’s Golden Age derives more from his beloved Ovid than from Genesis; cf. *Metamorphoses*, Book I. The prominent positions of the twin Paradises in the cycle testify both of Burnet’s millennialism and his Cambridge Platonism; see Nicolson, *Mountain Gloom and Mountain Glory.*

torical sensibility which aptly interprets Burnet's frontispiece as well: "Apocalypticism endows each of the time periods with a special significance, showing how the past anticipates and influences the present, how the present reflects and repeats the past, and how the determined future reveals the inevitability of the process leading to it."[30]

Kubrin assumed that the concept of Earth history as the completion of one revolution of a great cycle logically implies an eternal universe, or the idea of an eternal return. There is no evidence to conclude that Burnet shared this assumption although, as we shall see, materialists such as Charles Blount immediately appropriated Burnet's views to serve their own eternalistic cosmologies. But such appropriation requires a more historical explanation than merely the working out of alleged philosophical implications of Burnet's ideas. Burnet's position was not without historical precedent, for apocalyptic theological traditions had frequently invoked the contemplation of a great cycle as a providentially-bestowed technique for anticipating the end of time. Smoller writes:

> It is misleading, also, to stress the cyclical as opposed to linear nature of astrological history. The Arabic astrologers who developed Hindu notions of a 'world-year' erected systems that implied both a beginning and an end for the world. . . . one of the early translators of Arabic sources, Hermann of Carinthia, had foreseen the necessity of the end of the world in the stars. Particularly for D'Ailly, as well, astrological time was both cyclical and linear.[31]

This historical tradition (often orthodox) underlies Burnet's anticipation of the final conflagration. As a consequence, an alleged logical inconsistency between cosmic cycles and a finite duration of the universe fails as an historical explanation.

Regarding the millennium, Burnet took great pains to distinguish his premillennial views from the millennialism of radical enthusiasts:

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[30] Ardolino, 46.

[31] Laura Ackerman Smoller, *History, Prophecy, and the Stars: The Christian Astrology of Pierre D'Ailly, 1350–1420* (Princeton: Princeton University Press, 1994), 81. The context is Smoller's critique of the claims of Tullio Gregory and Krzystof Pomian that cyclical astrological time was essentially naturalistic and inherently contradictory to an Augustinian theology of linear and providentially-directed history. Smoller documents the significance of astrological calculations of the end of the world by orthodox theologians such as Pierre D'Ailly.

> For when they plac'd the kingdom of the Saints upon this Earth, it became more capable of being abus'd, by fanatical spirits, *to the disturbance of the World, and the invasion of the rights of the Magistrates, Civil or Ecclesiastical*, under that notion of Saints. And made them also dream of sensual pleasures, such as they see in this life: Or at least gave an occasion and opportunity to those, that had a mind to make the doctrine odious, of charging it with these consequences. All these abuses are cut off, and these scandals prevented, by placing the Millennium aright" [i.e., placing it after the conflagration].[32]

Since the nineteenth century, millennial views have been categorized in three major groups, each of which has many variations and subgroups: *Pre*millennialism such as Burnet's situated the return of Christ, and the first resurrection, *before* the millennium; *post*millennialism envisioned the return of Christ *after* a period of human progress—the millennium—which would lead up to a single general resurrection of the saints along with the wicked. Burnet also argued against *a*millennialists, who held that the millennium should be interpreted allegorically as an invisible heavenly kingdom already underway.[33] Postmillennialist and amillennialist views had a history of association with political subversion, as zealous saints would try to hasten along the millennium by political activity. Yet premillennialism was not free from radical overtones, either. Premillennialist Puritans deployed their eschatological views in support of Cromwell and their "No King but Christ" motto with hope of seeing the kingdom of God

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[32] Burnet, 358 (italics added).

[33] Although these terms are anachronistic for the seventeenth century, millennial views are difficult to discuss without using them. Roughly, Augustine and Calvin could be grouped with amillennialism, which generally prevailed in Reformed theological circles. Premillennialism was advocated by church fathers prior to Augustine such as Irenaeus and Justin Martyr. A number of radical medieval movements held premillennialist views, as did many sixteenth-century Lutherans, Anabaptists, and mid-seventeenth century Puritans such as the English scholar Joseph Mede (1586–1638). Isaac Newton and Joseph Priestley also tended toward premillennialist views. A contemporary of Burnet was Daniel Whitby (1638–1726), whose writings helped establish postmillennialism as perhaps the dominant view of the eighteenth century, before the revival of premillennialism in the nineteenth-century by dissenters such as J. N. Darby (1800–1882). C. I. Scofield (1843–1921) incorporated premillennial positions into the notes of his best-selling reference Bible. Literature on millennialism is voluminous, but the starting point remains Norman Cohn, *The Pursuit of the Millennium* (Oxford: Oxford University Press, 1970). Comprehensive works on English millennialism are Charles A. Patrides and Joseph Wittreich, eds., *The Apocalypse in English Renaissance thought and literature* (Ithaca: Cornell University Press, 1984), Peter Toon, ed., *Puritans, the Millennium and the Future of Israel, Puritan Eschatology 1600–1660* (Cambridge: James Clarke and Company, 1970), and Richard Bauckham, *Tudor Apocalypse: Sixteenth Century Apocalypticism, Millennarianism and the English Reformation from John Bale to John Foxe and Thomas Brightman*, Courtenay Library of Reformation Classics, no. 8 (Appleford, Oxford: Sutton Courtenay Press, 1978). Two helpful studies of major figures are Robert G. Clouse, "The Apocalyptic Interpretation of Thomas Brightman and Joseph Mede," *Journal of the Evangelical Theological Society*, 1968, 11: 181–193; idem, "Johann Heinrich Alsted and English Millennialism," *Harvard Theological Review*, 1969, 42: 189–207.

upon the Earth. This explains why the royalist Burnet was so eager, in the quote above, to dissociate his views from radical millennialism.[34]

Whether Burnet successfully resolved the potential for political subversion latent in millennialism, he was not alone, for there were many other Theories of the Earth with explicit apocalpytic concerns written in Britain in the late seventeenth century. For example, David Kubrin has shown how Isaac Newton's theories regarding the Earth were intimately related to his own apocalyptic speculations, and involved replacing the inner planets after their destruction by translocating the satellites of the outer planets.[35] William Whiston's concern with a cometary conflagration in his *New Theory of the Earth* (1696) has already been noted.[36] In another famous example, John Ray's *Miscellaneous Discourses Concerning the Dissolution and Changes of the World* (London: Printed for Samuel Smith, 1692) was a revision of a sermon on the Millennium given at Cambridge in the late 1650s:

> The sermon from the 1650s or 1660s which Ray used as the basis of his 1692 work had been concerned exclusively with the future dissolution of the world and

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[34] M. C. Jacob and W. A. Lockwood, "Political Millenarianism and Burnet's Sacred Theory," *Science Studies*, 1972, 2: 265–279. Jacob and Lockwood demonstrate that English scholars still displayed a great interest in the apocalypse in the late 1680s and 1690s. For example, Drue Cressener, *The Judgment of God upon the Roman Catholic Church; in a prospect of several approaching revolutions in explication of the Trumpets and Vials in the Apocalypse, upon principles generally acknowledged by Protestant interpreters* (1689) was read by Burnet in the spring of 1688, and Cressener in turn read Burnet's Theory that same spring also, with Burnet completing it by May. However, by focusing exclusively upon the Glorious Revolution of 1688 as the immediate political setting for the publication of the two last books, Jacob and Lockwood's analysis does not address the fact that Burnet had planned to include the two last books from the beginning, as is clear from the two first books and from the frontispiece. At that time Burnet most likely read the works of his friend Henry More, *Apocalypsis Apocalypseos* (1680) and *A Plain and Continued Exposition of the Several Prophecies or Divine Visions of Daniel, Which Have or May Concern the People of God* (1681). Moreover, Jacob and Lockwood's interpretation of Burnet's manuscript annotations has been challenged by Scott Mandelbrote, "Isaac Newton and Thomas Burnet: Biblical Criticism and the Crisis of Late Seventeenth-Century England," in *The Books of Nature and Scripture: Recent Essays on Natural Philosophy, Theology, and Biblical Criticism in the Netherlands of Spinoza's Time and the British Isles of Newton's Time*, Archives Internationales D'Histoire des Idées, no. 139, ed. James E. Force and Richard H. Popkin (Dordrecht: Kluwer Academic Publishers, 1994), 149-178.

[35] Kubrin, "Providence and the Mechanical Philosophy," 13-14 and 35. Kubrin deftly analyzes the development of Newton's fascinating Theory of the Earth in ch. 1, pp. 1-38; cf. also pp. 135-142 and 161-165. Although his ideas were at times reported before the Royal Society of London, Newton kept his views largely private, limited to a small circle of friends and correspondents which included Burnet, Whiston, and Halley. Hints are found in various editions of the *Principia* and *Opticks*, as Kubrin shows. Kubrin published an earlier version of chapter 1 as "Newton and the Cyclical Cosmos," *Journal of the History of Ideas* 28 (1967): 325-346.

[36] See "Whiston and Pseudoscience," beginning on page 296; cf. William Whiston, *An Essay on the Revelation of St. John* (London, 1706).

> the Millennium. And so too was the treatise of 1692 to be. Throughout his correspondence of the period... the work was always referred to as a discourse concerning the dissolution of the world.[37]

Discussing the millenarian context of Ray's views in some detail, Kubrin points out that Ray's discussions of the deluge and the creation of the world from chaos were deemed "digressions," and amounted to only 27 pages out of a total of 259.

§ 3. Reason and Cartesian Cosmology

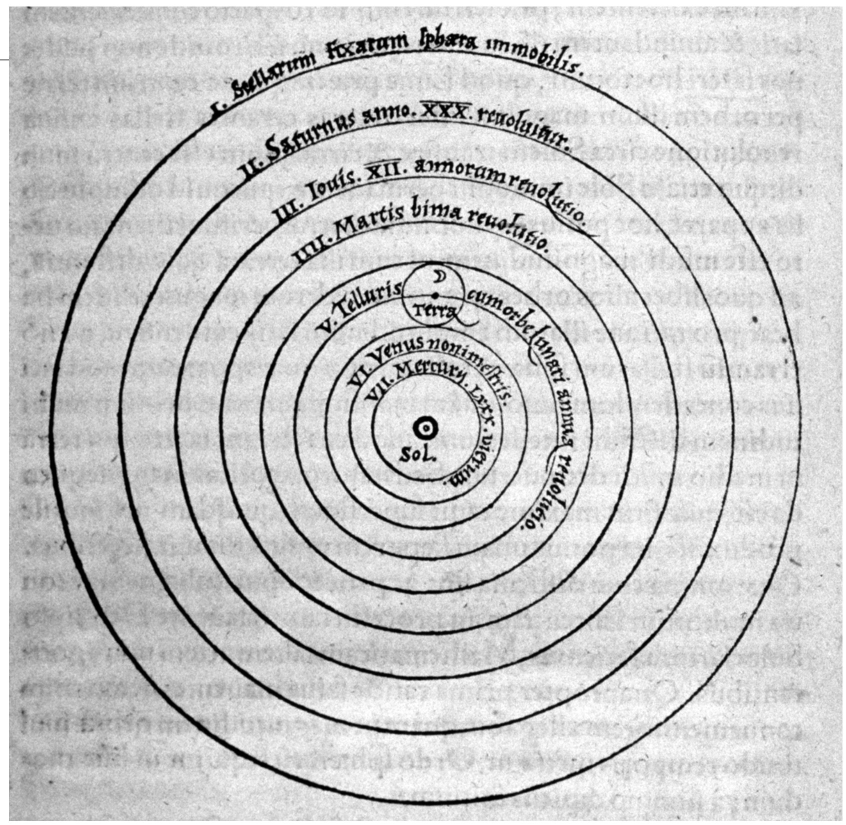

FIGURE 82. Nicolaus Copernicus, *De revolutionibus orbium coelestium* (1543). Book I, chapter 10. HSCI.

In combination with biblical motifs, cosmological conventions underlie the composition of Burnet's frontispiece. Burnet adopted a Copernican cosmology in which the Earth itself is a planet revolving in a heavenly orbit. A famous diagram from Copernicus' *On the Revolution of the Heavenly Orbs* (1543) depicts the heliocentric arrangement where the Earth, accompanied by its Moon, moves around the Sun in a great circle (Figure 82). Like a geometrical icon, this diagram's

[37] Kubrin, "Providence and the Mechanical Philosophy," 184.

visual aspects persuaded and compelled assent, with its clean elegance of circles revolving around circles.[38]

While Burnet's frontispiece is Copernican in that it depicts the revolutions of the Earth in a circular trajectory—as if the Sun were hidden in the center, in the area behind the title of the book—it is likely that Ptolemaic cosmology never boasted a more Earth-centered illustration. Although the Earth is displaced from the spatial center of the cosmos, its dislocation has not diminished its visual significance: the title and the cycle of globes combine in compositional effect to make the Earth both center and circumference. There was no need to picture the Sun: the cycle of globes as engraved here constitutes a new kind of revolution of an heavenly orb, where the globe is represented as passing through scenes of historical time rather than stations of ethereal space. Time is of the essence in this visual scheme: the temporal trajectory of a heavenly globe rather than its course through space determines its identity and defines its nature. Indeed, Burnet verbally asserted that the changes passed through by a planetary body over time are of greater magnitude than the differences between any two bodies separated by mere space:

> And I am apt to think that some two Planets, that are under the same state or Period, do not so much differ from one another, as the same Planet doth from itself, in different periods of its duration. We do not seem to inhabit the same world that our first fore-fathers did, nor scarce to be the same race of men.[39]

One and the same planetary orb constitutes a plurality of worlds in a temporal dimension. This is neither a terrestrial nor a cosmic perspective. Unlike the perspective of an observer in

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[38] The simplicity of the Copernican system was perceived as one of its greatest attractions by early supporters such as Thomas Digges. Yet twentieth-century philosophers frequently point out that in actuality the system was complex, for at least in terms of the total number of circles it required more than Ptolemy's models. See, for example, Imre Lakatos, "Why did Copernicus's Research Programme Supersede Ptolemy's?," in *The Methodology of Scientific Research Programmes: Philosophical Papers*, ed. John Worrall and Gregory Currie (Cambridge: Cambridge University Press, 1978), 168-192.

[39] Burnet, 140. Burnet elaborated on the previous sentence with a lament for the lost Golden Age which, speaking of human actors upon a stage, echoed the "Theater of the World" metaphor established by his reference to the "scenes" of Earth history: "Our life now is so short and vain, as if we came into the World only to see it and leave it; by that time we begin to understand our selves a little, and to know where we are, and how to act our part, we must leave the stage . . . ." Cf. p. 241, 249. In the frontispiece the universe is the theater and the Earth is the play with a definite beginning, middle and end in which humans and the Earth are co-actors.

outer space,[40] still less of one confined to the present scene of the world, this engraving views the Earth from eternity, where it lies encompassed by the divine Ruler who stands not only omnipresent to all locations in space but equipresent to all Earthly times.[41] Through contemplation of the "revolutions of our natural world" Burnet holds out to the reader the hope of transcending the present time with such a beatific vision.[42]

To understand how Burnet envisioned the first world to arise out of chaos we should take note of a few diagrams from the *Principia Philosophiae* (*Principles of Philosophy*, 1644) of René Descartes (1596–1650).[43] Burnet's work was inspired by the cosmology of Descartes, indeed, the latter's mechanistic principles pervade Burnet's Theory just as, in the Cartesian conception, the primary fiery element pervades the world.

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[40] In his study of the development of artistic depictions of the pre-human world as viewed from an Earth-bound perspective, Martin Rudwick twice refers to Burnet's frontispiece as a view from outer space; *Scenes from Deep Time*, 255 n. 4 and 256 n. 10. While Rudwick is correct that any single global scene may depict a view from outer space, the composition of the frontispiece as a whole depicts a *temporal* sequence.

[41] C. A. Patrides writes that an apocalyptic view of time: "delineates the future not at the expense of the past but in terms of the past. . . . The fundamental presupposition is that the course of history can be accurately perceived solely from Heaven, for . . . it will be recognized not only that the past and present are anticipatory of the future but that the future is inherent in the past and that both are present in the present. In this respect the numerous allusions to times past as if they are times present or time future . . . proclaim the concurrence of all events in the eyes of God." Quoted in Ardolino, 46.

[42] Near the end of Book II, Burnet characterized his vision of the Earth in the rhapsodic spirit of intellectualist platonic theology, writing that "as it is necessary to suppose, that there is an Idea in the Divine Understanding of all the mass of Beings produc'd or Created, according to the several ranks and orders wherein they stand; so there is also an Idea there, according to which this great Frame moves, and all the parts of it, in beauty and harmony. And these two things, The Essences of all Beings, and the Series of their Motions, compose the MUNDANE IDEA, as I may so call it; or that great All-comprehensive Thought in the Divine Understanding, which contains the System of Universal Providence, and the *state of all things, past, present, or to come*. This glorious Idea is the express Image of the whole Creation, of all the works of God, and the disposition of them; here lie the mysteries of Providence, as in their Original; *The successive Forms of all Nature; and herein, as in a Glass, may be view'd all the Scenes of Time or Eternity*. This is an Abysse of Sacred Wisdom, The inexhausted treasure of all Science, The Root of Truth, and Fountain of Intellectual Light; *And in the clear and full contemplation of this is perfect happiness, and a truly beatifick Vision*." Burnet, 224 (original capitalization; italics added). Near the end of Book IV, Burnet returned to this theme, explaining that for resurrected saints in the millennium the "contemplation of God and his Works, comprehends all things." As part of the "Mundane Idea," the "Theory of the Earth will be a common lesson there: carried through all its vicissitudes and periods from first to last, till its entire revolution be accomplish'd." Burnet concluded, "Do but imagine, that they will have the Scheme of all humane affairs lying before them: from the Chaos to the last period. The universal history and the order of times.... Do imagine this, I say, and you will easily allow, that when they contemplate the beauty, wisdom, and goodness of the whole design, it must needs raise great and noble passions, and a far richer joy than either the pleasures or speculations of this life can excite in us.... The whole Theater resounding with the praises of the great Dramatist, and the wonderful art and order of the composition." Burnet, 369–371.

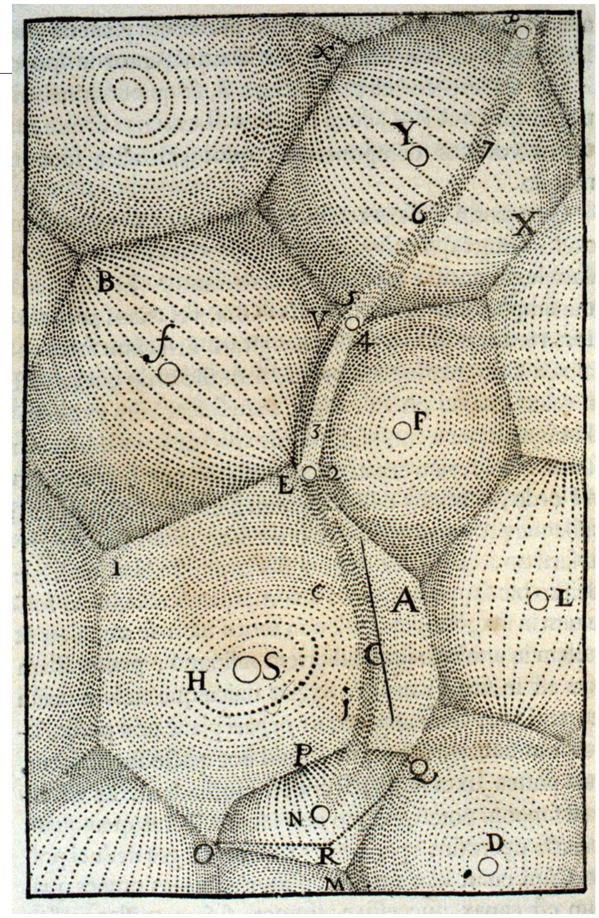

FIGURE 83. Descartes, *Principia philosophiae* (1644), vortices with comet. Later *Plate VI.* HSCI.

For Descartes, the planets were carried around the Sun in a great vortex of whirling matter. Descartes introduced a figure that was later known as *Plate VI* to show the elements constituting a vortical system and how they form the Sun and fixed stars (Figure 83). Our own Sun (S) lies in the center of a large vortex, comprised of matter whirling in the direction A-E-I. A neighboring vortex, centered on F, rotates in the direction A-E-V. An indefinite number of vortices, of varying sizes, exist; one for each fixed star, on which each vortex is centered.[44]

[43] Eric J. Aiton, *The Vortex Theory of Planetary Motions* (London: MacDonald, 1972), chapter 2, reprints some of the cosmological diagrams in a masterful summary of Cartesian physics. David Oldroyd analyzes Descartes' diagrams for the formation of the Earth, although without paying significant attention to their appropriation by Burnet; "Mechanical Mineralogy," *Ambix* 21 (1974), 157-178. All citations will be to René Descartes, *Principles of Philosophy*, trans. R. P. Miller and V. R. Miller, Synthese Historical Library, 24 (Dordrecht: D. Reidel, 1983); hereafter simply "Descartes." This is a complete English translation, but to facilitate reference to other editions citations will include, prior to the pagination in this edition, the Part and Article numbers.

[44] *Principia Philosophiae* Part III, Articles 53–54, 65, 115; Descartes, 110–111, 118, 147.

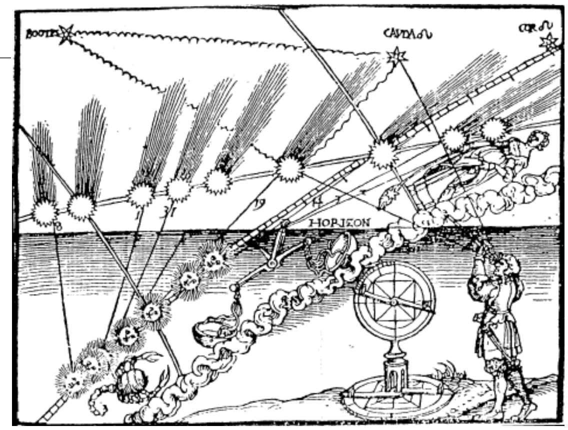

FIGURE 84. Peter Apian, Comet, *Ein Kurtzer Bericht* (1532).

Depicting local motion or change of place over time, of course, is nothing new. For example, consider Figure 84, Peter Apian's (1495–1532) striking depiction of the changing positions of a comet relative to the horizon (*Ein Kurtzer Bericht*, 1532). The Sun is shown in various positions along the ecliptic. Lines are drawn from the Sun at each of its depicted positions to the corresponding positions of the comet for each evening. Figure 84 corresponds to the southeastern horizon before sunrise in autumn.[45] A row of clouds beneath the constellation figures stylistically separates the astronomer from the heavens.[46]

For Apian, as for Aristotle and Ptolemy, comets physically were located below the Moon and above the clouds.[47] Figure 84 shows with great clarity, from an Earthbound perspective, how the tail of the comet changes in orientation over time so that it always points away from the Sun, even when the Sun lies below the horizon.[48] We shall soon refer to a much later illustration of cometary tails, drawn from the perspective of outer space, but note for now that

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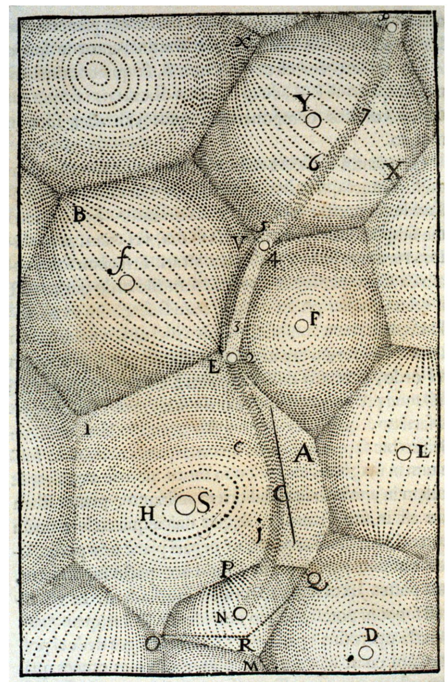
45 The ecliptic is the path the Sun follows as it moves roughly eastward against the background of fixed stars, completing one full circle around the sky every year. On the diagram the ecliptic is marked in one-day intervals. Zodiac constellations are those constellations which include some portion of the ecliptic, and in which the Moon and planets are seen. Shown on the diagram are figures for three of the twelve zodiac constellations: Scorpius (the Scorpion), Libra (the Scales or Balance), and Virgo (the virgin with a sheaf of wheat). These figures do not overlay the stars of the corresponding constellations (Libra is actually quite small, smaller than Scorpius, and Virgo is the largest of zodiac constellations). The constellation figures identify which portion of the ecliptic is visible in this horizon scene (only Virgo is above the horizon at the moment depicted; Libra is about to rise). No figure is drawn for Leo the Lion, which is the next zodiacal constellation higher in the sky to the west of Virgo. The heart of the Lion, *Cor* ♌ (given its present name Regulus by Copernicus), is the star located almost on the ecliptic, the brightest star of Leo. *Cavda* ♌ is the bright star of Leo's tail, now known as Denebola. A triangulation is being performed to situate the comet's location relative to Denebola and Arcturus (the bright star of the constellation Boötes the Herdsman).

46 A similarly-stylized band of clouds lying between the terraqueous globe and the sublunar sphere of fire can be seen in Apian's section of the Earth-centered Ptolemaic cosmos (Figure 57 on page 399).

Apian's diagram depicts the comet and the Sun as moving through space over time. At each new occasion the Sun remains the Sun and the comet is still a comet. For Apian, the significant changes in both the Sun and the comet are changes of location and orientation, not of identity or nature. In the diagrams of Descartes and (a generation later) Burnet, however, visual conventions were developed to represent motion where the bodies change not only their position with respect to one another, but also alter their identity and nature.

Descartes' diagram and Burnet's frontispiece depicted the changes transforming a body of a given nature into one of a different kind. In Descartes' cosmology, a new vortical system might arise at any time, grow stronger, then eventually weaken and dissolve. In the process a fixed star might become a wandering comet or an Earth-like planet. Descartes' Figure 83 on page 453 (reprinted right) illustrates something of this temporal transformation. From time to time, a vortex might diminish in force (as in N), and be entirely absorbed into a neighboring system (so that vortex S might extend its boundary from OPQ to ORQ). The fixed star N, by now encrusted with sunspot material, would become a planet or a comet in the new system S. For example, if star N were to be swept up into vortex S, it would initially



[47] Figure 84 superimposes two visual reference frames: one provides information about the *apparent* location of the comet (against the background stars) and the other reflects tacit assumptions regarding the *physical* location of the Sun and the heavens, excluding the comet. The horizon line lies in the *apparent* location reference frame pertaining to the comet, and the arc of clouds indicates the *physical* location reference frame. The fact that the comet is drawn above the ecliptic on the left side of the diagram, as it moves east of Virgo, does not mean that it has physically moved farther out in space from the Earth so that it is now beyond the Sun, but only that its apparent location against the background of fixed stars has moved northward from the ecliptic relative to the horizon. The only affirmation Apian intended regarding the physical location of the comet was that it moved above the clouds, not that it was near to or higher than the Sun.

[48] On Apian's theory of comets as lenses focusing the Sun's light in a beam pointing the opposite direction see Peter Barker, "The Optical Theory of Comets from Apian to Kepler," *Physis* 30 (1993): 1–25; and Peter Barker and Bernard R. Goldstein, "The Role of Comets in the Copernican revolution," *Studies in History and Philosophy of Science* 19 (19xxx): 299–319.

move toward A. If less solid, it would then descend toward S and become a planet; planets of lesser density would fall farther and settle nearer to the center of the vortex. If more dense and already solidified (by a well-developed surface layer of sunspot matter) the migrating N would recede from S and become a comet. As a comet it would follow a trajectory parallel to the line drawn tangent at C, until leaving vortex S at 2. From 3 to 4 it travels in vortex AEV, centered on F, and from 5 to 8 it moves within vortex Y.[49]

In contrast to Apian's diagram, Descartes' illustration depicts the formation of a comet in time, not merely its motion in space. Although depicting vortices rather than the globe of the Earth, Descartes' plate, with its shifting systems and wandering stars, conveys a strong visual message not merely that the extent of space is indefinitely vast, containing worlds beyond worlds, but above all that the heavens or vortices and all the bodies they contain are utterly mutable and temporal by nature. The heavens are corruptible; time alone will ruin a world.[50] There is no perpetuity of particular parts; only the universe as a whole is indefinitely stable.

Despite Burnet's adoption of the general cosmology and mechanistic principles of Descartes, with all of the temporality they implied, there may appear to be a small contrast, or innovation, with Burnet's appropriation. For Descartes, a Sun would naturally progress to become a planet or a comet. Burnet's system at first appears to reverse the process: beginning with a watery chaos, a planet naturally arises and, after a deluge and a fiery conflagration, proceeds on to become a bright star at the end. However, it turns out that for Burnet the Earth was originally a star, from which the watery chaos was derived much as Descartes had

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[49] *Principia Philosophiae* Part III, Articles 115–127; Descartes, 147–157.

[50] The Cartesian cosmos extended to the heavens themselves the corruptibility attributed by Aristotle to the sublunar realm. The heart-stopping phrase that "time alone will ruin a world" is a quotation from Bernard le Bovier de Fontenelle, *Entretiens sur la pluralité des mondes* (Paris, 1686); *A Plurality of Worlds*, trans. Mr. Glanvill (London: Printed for R. Bentley and S. Magnes, in Russel-street, in Covent-Garden, 1688), 149. Fontenelle provided a readable and quite entertaining account of Descartes' cosmology in this little book, which was a bestseller for nearly a century. Seventeenth-century scholastic views of the heavens also frequently held that they are corruptible; cf. Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994), chapter 10, "The Incorruptibility of the Celestial Region," and William H. Donahue, *The Dissolution of the Heavenly Spheres, 1595–1650* (New York: Arno Press, 1981).

described. In the final consummation, Burnet explained, the Earth completes one revolution of the cycle depicted on the frontispiece and is thereby restored to its stellar condition:

> But if Planets were once fixt Stars, as I believe they were; their revolution to the same state again, in a great circle of Time, seems to be according to the methods of Providence; which loves to recover what was lost or decay'd, after certain periods: and what was generally good and happy, to make it so again; All Nature, at last, being transform'd into a like glory with the Sons of God.[51]

Afterward, Burnet continued, going well beyond Descartes' account, the new star will be translocated to its own vortex system among other fixed stars.[52]

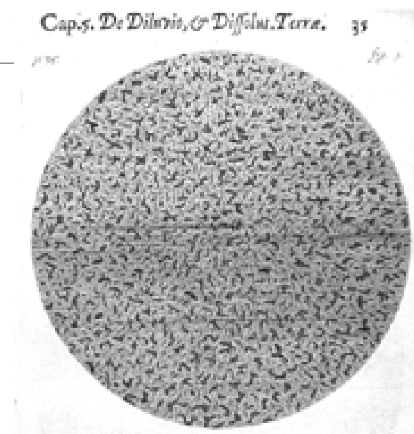

FIGURE 85. Burnet's geogonic series, Chaos section. *Telluris Theoria Sacra* (1681), Book I, ch. 5, p. 35. HSCI.

To explain the manner in which a habitable world would naturally arise from an initial chaos, Burnet resorted to visual demonstration. He began with the original chaos, greatly enlarged compared to its cameo version in the frontispiece (Figure 85). As with the frontispiece,

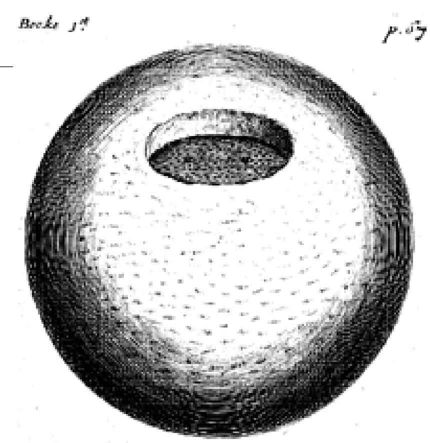

FIGURE 86. Burnet's Paradisiacal globe. Theory of the Earth (1684), Book I, p. 67. HSCI.

the temporal dimension again is paramount: the redrawn figure of chaos does not stand by itself, but anchors the beginning of a new series of seven global sections and views, a geogonic series which does not correspond to the

[51] Burnet, 376.

[52] "And I am of opinion, that the Earth after the last Day of Judgment, will be chang'd into the nature of a Sun, or of a fixt Star: and shine like them in the Firmament. Being all melted down into a mass of Aethereal matter, and enlightening a Sphere or Orb round about it." Burnet, 376.

seven scenes of the frontispiece. The last diagram concludes the new series with a redrawn version of the Paradisiacal globe reminiscent of the second scene of the frontispiece (Figure 86).[53] Thus the geogonic sections are a series within a series, moving from chaos to a habitable world, thereby revealing the progression of the globe between two adjacent scenes as depicted on the frontispiece.

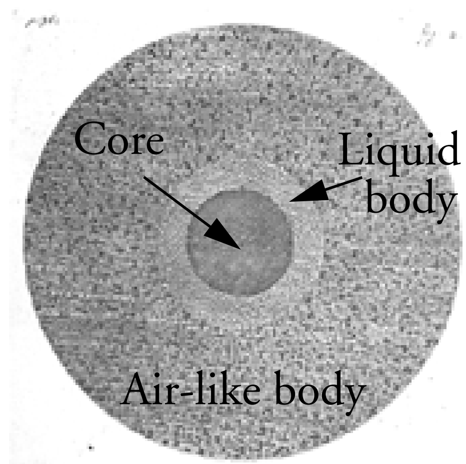

FIGURE 87. Burnet's geogonic series, second figure. *Telluris Theoria Sacra* (1681). Book I, ch. 5, p. 36. HSCI. (labels added)

The second diagram in Burnet's geogonic series (Figure 87) moves one step away from the chaos of elements confusedly mingled together. At this time the heavier parts of the chaos have sunken down by gravity to form a hard core. Burnet will later locate a fiery center within this core, but he chose not to depict that here, focusing at this time only upon those circumstances giving rise to a habitable exterior surface.[54] As there would be two interior regions, so there are two external: The outer parts have divided in turn, by gravity, into two layers of bodies: beneath is the liquid body, watery and containing various liquors; above, a volatile, air-like body reaches as high as the Moon. These are the two outermost layers of Figure 87.

[53] This global view of the Paradisiacal Earth first appeared in the 1684 English edition, along with the first version of the frontispiece. In editions thereafter it is usually included. Otherwise, the geogonic series is found in all editions of Burnet from the first 1681 Latin edition through the eighteenth century, and thus predates the frontispiece.

[54] Burnet later explained (Book IV, chapter II): "In forming the first Earth, I supposed the Chaos or confus'd Mass to reach down to the Center, I did that onely for the ease of our imagination; so that the whole Mass might appear more simple and uniform. But in reality, that Chaos had a solid kernel of Earth within... and that matter which fluctuated above in the regions of the Air, was the true Chaos...." Burnet, 324.

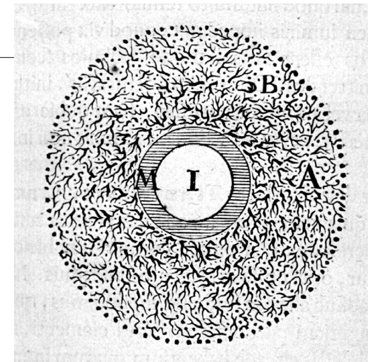

FIGURE 88. René Descartes, *Principia philosophiae* (1644), star-to-comet cosmogonic section. Later *Plate XVI*. LH.

Consider the precedents, both visual and conceptual, provided at this stage by Descartes. In the *Principles of Philosophy* Descartes illustrated the conversion of a star into a comet (Figure 88). The first fiery element remains in the interior region I [*ignis*?], yet is covered by "a very opaque and dense body" M [*macula*?], made from the consolidation of sunspots.[55] In Descartes' and Burnet's accounts the two interior regions of the globe are quite similar; moreover, like Burnet, Descartes minimized the internal regions as inconsequential for his physics of the Earth: "But these two inner regions concern us very little, because no one has reached them alive."[56]

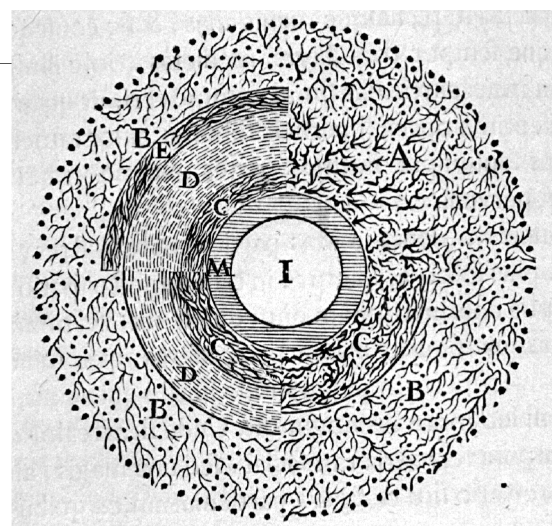

FIGURE 89. René Descartes, *Principia philosophiae* (1644), comet-to-planet cosmogonic section. LH.

From the exterior region A, Descartes derived every kind of material and structure found on the surface of the Earth. To depict this lengthy process, the conversion of a comet into a planet, he employed a very interesting visual device, almost a wheel of time, incorporating a sequence of four stages into one figure (Figure 89). To read this section imagine spokes vertically and horizontally dividing the wheel into four quadrants. Then number the quadrants clockwise starting at the top, so that the first quadrant lies in the upper right,

[55] *Ignis* and *macula* are my interpolations, not specified explicitly by Descartes.
[56] *Principia Philosophiae* Part IV, Articles 3–14; Descartes, 182–186.

the second in the lower right, etc. The first quadrant depicts the same time as the previous plate, with interior regions I and M, and exterior region A. With the second quadrant the external region A has divided into two layers, B and C, much like Burnet's *figure 2* (except that Burnet declined to depict the central fiery core until later in the series; cf. Figure 87).

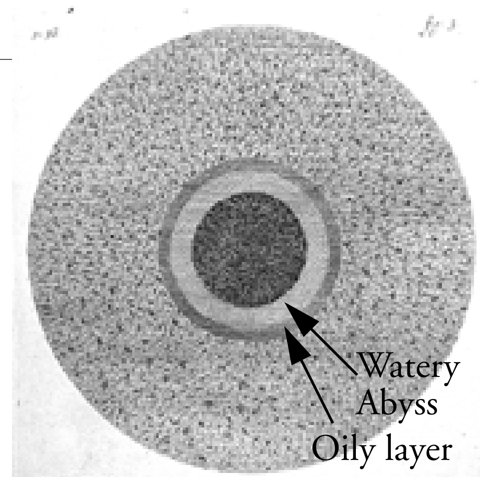

FIGURE 90. Burnet's geogonic series, *fig. 3*. *Telluris Theoria Sacra* (1681). Book I, ch. 5, p. 38. HSCI.

Explanation. "Abyss" and "Oily layer" labels added.

With his third figure (Figure 90) Burnet envisioned a division of the liquid body of the previous diagram, located as we have seen beneath the large outer air-like body. Two liquid layers result: a watery layer underlies a lighter-weight oily layer. Burnet hints that the lower watery layer is the Abyss, and the oily liquor above it the "face of the Deep."

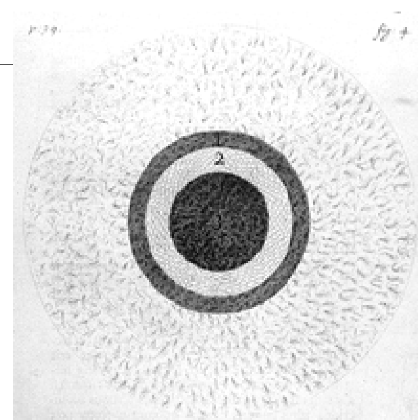

FIGURE 91. Burnet's geogonic series, *fig. 4*. *Telluris Theoria Sacra* (1681). Book I, ch. 5, p. 39. HSCI.

Explanation. 1=oily layer thickening into crust. 2=watery abyss. 3=core.

In Burnet's fourth figure (Figure 91) terrestrial particles from the outer airy region have very gradually settled (like exhalations or snowflakes) upon the oily liquor, forming a slime upon the waters. This terrestrial slime is a thin, light film of earth which eventually thickens into a hard crust (layer 1 in the figure) that Burnet repeatedly designates as the "Orb of the Earth."[57] The fourth figure shows the airy region beginning to clear up as the terrestrial particles fall out.

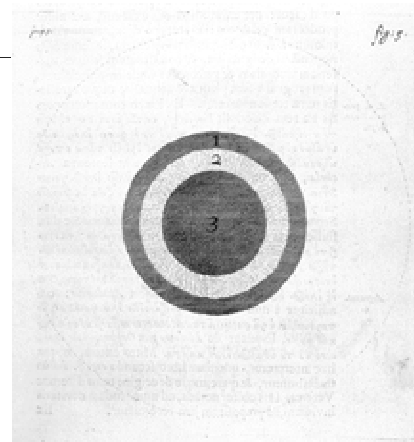

FIGURE 92. Burnet's geogonic series, *fig. 5*. *Telluris Theoria Sacra* (1681). Book I, ch. 5, p. 41. HSCI.

The hardened, thickened crust is depicted as layer 1 in *figures 4* and *5*. This crust is "the first concretion, or firm and consistent substance that rise upon the face of the Chaos."[58] The watery abyss lies beneath the crust as layer 2. In *figure 5* the air no longer reaches the height of the Moon, so the section is severely contracted in diameter (Figure 92). Many editions note this detail with a dotted line drawn in a large outer circle representing the orbit of the Moon (the former extent of the chaos).[59]

§ 4. Antiquity and Classical Learning

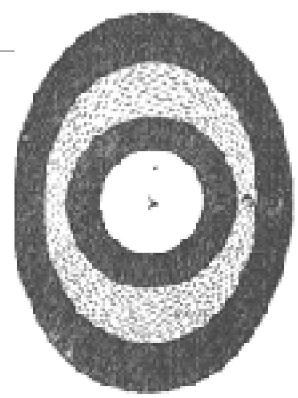

FIGURE 93. Burnet's ovoid section, *fig. 7*. *Telluris Theoria Sacra* (1681). Book I, ch. 5, p. 46. HSCI.

Description. Rotated 90° to make Earth's axis vertical.

Burnet's geogonic series reflects the appropriation of classical antiquities as well as Cartesian cosmology, especially with respect to

[57] For example, cf. Burnet, 58–61, where the phrase occurs six times in four pages.

[58] Burnet, 58.

[59] This line is shown, for example, in the first 1681 London Latin edition, the 1699 Amsterdam Latin edition, and the 1703 Hamburg German edition.

the figure of the Earth and Burnet's use of climatic zones and biogeography. With Burnet's *figure 7* (Figure 93) the internal fiery core (A) is shown for the first time, to suggest that the interior and exterior regions of the Earth form a Mundane Egg. The central yolk is of fire (A), with a membrane around it forming the outer layer (B) of the interior region (which was layer 3 in *figure 5*). The exterior region includes the watery abyss as the white of the egg (C), and the outer crust as its shell (D). In the original figure the Earth's axis runs horizontally, so that according to Burnet the globe is not precisely spherical but ovoid (egg-shaped), with the polar diameter greater than the diameter at the equator.[60]

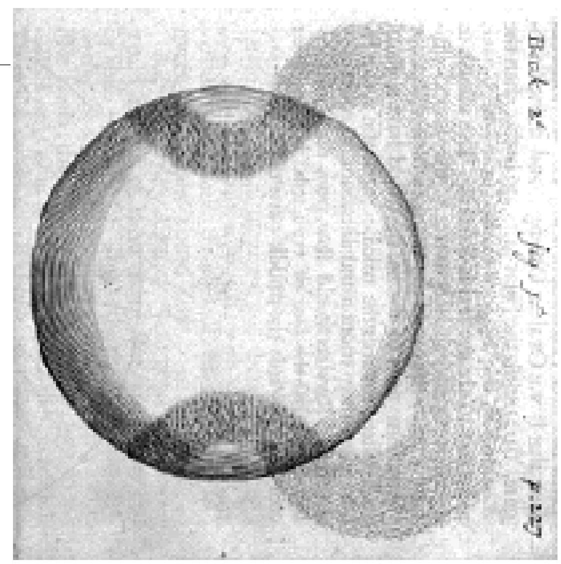

FIGURE 94. Burnet's antediluvian water cycle, *fig. 1,* p. 227. *Theory of the Earth* (1684). LH.

Description. Rotated 90° to make the Earth's axis vertical.

The ovoid figure of the Earth, elongated at the poles, played a crucial role in Burnet's Theory of the Paradisiacal world. At that gentle time water vapors rose at the equator because of the intense heat of the Sun.[61] Because of the vigorous motion of their heated state the vapors pushed toward the cooler (and higher) poles, condensing there in an uninterrupted mist (Figure 94).[62] Because in Burnet's Theory the surface of the Earth is farther from the

[60] The convention of placing north at the top was established with seventeenth-century depictions of the Moon and was thereafter followed for depictions of all the planets, only gradually becoming a standard for terrestrial maps; Scott L. Montgomery, *The Moon and the Western Imagination* (Tucson: University of Arizona Press, 1999), 132. To avoid confusion among modern readers, I have rotated this and following illustrations, when necessary, to keep the Earth's axis vertical.

[61] As we will see, Burnet argued that the paradisiacal Earth diurnally rotated on its axis perpendicularly to the plane of its revolution around the Sun, so that the equator coincided with the ecliptic (i.e., the apparent path of the Sun). The present obliquity of the ecliptic results from the crustal collapse at the Deluge. The tilting of the Earth destroyed the former world's uniform climate, in which antediluvians had enjoyed a perpetual spring without seasonal variations.

center at the poles, the liquid water condensed in the polar lakes flows *downhill* toward the equatorial zones (Figure 95). Obviously, if the figure of the Earth were not elongated at the poles, this conception of the antediluvian water cycle would have been impossible. Because of the necessity for watering the paradisiacal

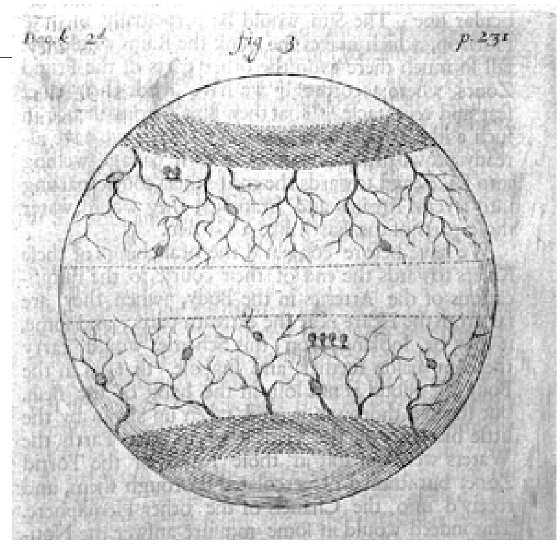

FIGURE 95. Burnet's antediluvian water cycle, fig. 3. *Theory of the Earth* (1684), Book I, ch. 5, p. 169. LH.

Description. Earth's axis is vertical.

globe by this means, Burnet's *Theory of the Earth* and an elongated figure of the Earth were joined together, never to be torn asunder.[63]

The figure of the Earth as an egg-shaped globe, or prolate spheroid elongated from pole to pole, was not essential to the Cartesian system. Descartes himself seems to have implied it,[64] and it was endorsed by later vortex theorists such as Johann Bernoulli and Dortous de Mairan. However, the Cartesian philosopher Christiaan Huygens predicted that the Earth was instead an oblate spheroid, flattened at the poles and bulging around the equator. Other Frenchmen (e.g., Jean-Dominique Cassini, Jacques Cassini) empirically determined to their satisfaction, on the basis of geodetic measurements in France, that the Earth was elongated at

62 Thus there was no *rain* (or rainbow) before the Deluge, confirming Burnet's interpretation of the covenant of the rainbow in Genesis 9:13. In Burnet's view, his Theory's sketch of the antediluvian water cycle was corroborated by the mists described in Genesis 2:5-6.

63 Figure 94 and Figure 95 were new to the 1684 English edition. They are the first and third of a series of three representations of the paradisiacal water cycle which was included in many subsequent editions. The second of the three, not reproduced here, is a geometrical diagram to illustrate that water flowing from the poles toward the equator moves downhill, or closer to the center of the Earth. On the importance of hydrological theories in seventeenth-century physicotheology see Yi-Fu Tuan, *The Hydrological Cycle and the Wisdom of God: A Theme in Geoteleology* (Toronto: University of Toronto Press, 1968).

64 There was plausible physical reasoning for this conclusion involving the downward pressure exerted by the vortex matter at the equator; cf. Descartes, Part IV, Articles 23, 27.

the poles. While consistent with Descartes' prediction this conclusion was not derived from Cartesian cosmology, so it was not inevitable that the figure of the Earth would come to play a crucial polemical role in debates over Cartesian natural philosophy.[65] Moreover, in 1680 Isaac Newton raised no objections to Burnet's ovoid figure of the Earth. After learning of Hooke's Theory which entailed a larger equatorial than polar diameter, Newton's views changed.[66] By the appearance of the *Principia* six years later, Newton's physics unquestionably specified that the Earth must be an oblate spheroid, flattened at the poles.[67]

Burnet's Theory of the Earth helped to solidify a widespread impression that Cartesian cosmology required an egg-shaped globe. After the appearance of the *Principia*, British Newtonians found a conspicuous polemical foil in Burnet's advocacy of an elongated globe in the name of Cartesian cosmology. William Whiston and John Keill (1671–1721) mounted blistering attacks upon Burnet's Theory by marshalling what evidence was then available to argue that the Earth was an oblate spheroid, hoping to kill the two birds of Burnet's world-making and Cartesian cosmology with one Newtonian stone.[68]

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65 See Eric J. Aiton, *The Vortex Theory of Planetary Motions* (London: MacDonald, 1972); John Greenberg, "Mathematical Physics in Eighteenth-Century France," *Isis*, 1986, 77: 59–78; Mary Terrall, "Representing the Earth's Shape: The Polemics Surrounding Maupertuis's Expedition to Lapland," *Isis*, 1992, 83: 218–237; and John L. Greenberg, *The Problem of the Earth's Shape from Newton to Clairaut: The Rise of Mathematical Science in 18th Century Paris and the Fall of "Normal" Science* (Cambridge: Cambridge University Press, 1996).

66 That Newton did not object in 1680 to Burnet's prolate spheroidal figure of the Earth is pointed out by Kubrin, "Providence and the Mechanical Philosophy," 162, citing Newton's *Correspondence*, Vol. 2, p. 329. Kubrin documents that Hooke and John Aubrey believed that after 1680 Newton obtained the idea of the oblate figure of the Earth from Hooke; Kubrin, 162-165.

67 On Newton, see the *Principia*, Book III, Proposition XVIII; *Mathematical Principles of Natural Philosophy*, trans. Andrew Motte (1729) and Florian Cajori, 2 vols. (Berkeley: University of California Press, 1934), 424ff. The resemblance of the title of Newton's work to Descartes' seems deliberate, given the significance of the two added adjectives.

68 The figure of the Earth is the subject of the sixth chapter of John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698). Keill was never known to mince words: "It seems to me that the Theorist in this part has endeavoured to give us a proof of his great skill in Logicks, for he from a possible supposition, has endeavoured directly to prove its contradictory, that is, because all Bodies do endeavour to recede from the Axis of their motion, therefore they will endeavour to go to the Axis of their motion." Keill, 89. In the following twenty pages Keill discussed pendulum experiments at the equator (which had been known to Huygens), Huygens' own analysis of centrifugal motion and, of course, Newton's *Principia*, arguing that the Earth is an oblate spheroid such as would be produced by a rotating spherical chaos, contrary to the conclusion of Burnet. For the effect of Maupertuis' rhetoric in joining Cartesian physics and the elongate spheroid in France see John L. Greenberg, "Mathematical Physics in Eighteenth-Century France," *Isis* 77 (1986): 59–78.

By appropriating the classical image of the world as a cosmic egg, however, Burnet believed he had secured valuable testimony corroborating his Theory with the authority of ancient wisdom. Many early modern scholars shared a belief that the ancients had a pristine wisdom through which they understood the order of nature profoundly enough that contemporary discoveries were but a restoration of the formerly-known truths. The ancients were believed to have encoded that knowledge in emblems and myths which were passed down to their descendants long after the original truths had been lost or forgotten. None other than Isaac Newton believed that the plan of the Solomonic Temple demonstrated that Solomon had grasped his inverse square law for the force of universal gravitational attraction.[69] Burnet thought that the temple plan confirmed his three-fold Theory of the Earth:

> I have often thought also, that their first and second Temple represented the first and second Earth or World; and that of Ezekiel's, which is the third, is still to be erected, the most beautiful of all, when this second Temple of the world shall be burnt down.[70]

William Whiston held that "Arts and Sciences were invented and improved in the first Ages of the World, as well as they since have been." He could deploy the theory of a universal Deluge to defend this belief, since a global catastrophe neutralized the force of "the greatest Objection against this Proposition," *viz.*, "the Ignorance and Barbarity of the Ages after the Deluge."[71] This practice of seeking *prisca sapientia* interpretations of ancient texts was popularized by

[69] See P. M. Rattansi and James E. McGuire, "Newton and the Pipes of Pan," *Notes and Records of the Royal Society of London*, 1966, 21: 108–143, for a perceptive and influential analysis of what is often referred to as the tradition of ancient wisdom, philosophy or theology; *prisca sapientia, prisca philosophia*, or *prisca theologia*. Another study is Daniel P. Walker, *The Ancient Theology* (Ithaca: Cornell University Press, 1972). Casini has published Newton's "classical scholia" in their entirety, and in the process corrects several misreadings by McGuire and Rattansi; Paolo Casini, "Newton: The Classical Scholia," *History of Science*, 1984, 22: 1–58. Casini demonstrates that seventeenth-century *prisca* traditions were not monolithic; different strands representing writers of contrasting tendencies were often mixed together heterogenously in a common literary substrate. Moreover, he cautions that interpreters of the *prisca* traditions did not discover new doctrines by reading them there, but were guided by their own discoveries as they sifted ancient testimony to find hidden confirmation for what they already knew.

[70] Burnet, 201.

[71] Whiston, *New Theory*, 264. The deluge explained how the *prisca sapientia* could be lost, and replaced by ignorance and barbarism. This argument has an ancient lineage, and echos of it may be found in Josephus (whose works Whiston edited; cf. *Antiquities of the Jews*, Book 1, chapter 2). Advocates of the eternity of human life on Earth, such as Philo and Seneca, argued analogously, invoking cataclysms of fire or water to explain the present existence of barbarity and apparent lack of progress of civilization in historical time.

Cambridge Platonists such as Henry More, Anne Conway, and Ralph Cudworth, although it was resisted by humanist scholars such as Richard Bentley and Restoration theologians such as Edward Stillingfleet.[72] The efforts of Stillingfleet, Bentley and others notwithstanding, *prisca sapientia* traditions which emphasized the evidential role of ancient texts in support of various Theories retained a powerful appeal to many writers through the eighteenth century, as can be seen as late as John Whitehurst's Theory of the Earth.[73]

The metaphor of the universe as a cosmic egg was a repeated and consistent motif of ancient mythology and tradition, advocated by cosmological thinkers from Greece to China. The breadth of appeal of this image may be illustrated with a few examples. For instance, the "Orphic egg" was a frequent cosmological motif in the Neoplatonic tradition:

> The arrangement which we have assigned to the celestial sphere the Orphics say is similar to that in eggs: for the relation which the shell has in the egg, the outer heaven has in the universe, and as the aither depends in a circle from the outer heaven, so does the membrane from the shell.[74]

More popularly, a striking section of an ovoid cosmos accompanied a medieval vision of St. Hildegard of Bingen (1098–1179; Figure 58 on page 405). Ovoid representations of the cosmos also appeared in "Zodiac Man" illustrations such as the one drawn by the Limbourg brothers for a famous book of hours, *Les Très Riches Heures du Duc de Berry* (1413–1416).[75] In the early seventeenth century, John Dee speculated upon the riddle of the Mundane Egg

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72 Ralph Cudworth, *True Intellectual System of the Universe* (1678); Edward Stillingfleet, *Origines Sacrae* (1662). Cf. Anthony T. Grafton, *Defenders of the Text: The Traditions of Scholarship in an Age of Science, 1450–1800* (Cambridge: Harvard University Press, 1991), Introduction.

73 John Whitehurst, *An Inquiry into the Original State and Formation of the Earth: Deduced from Facts and the Laws of Nature* (London: Printed for the author, by J. Cooper, 1778). On Whitehurst see "Whitehurst's Enigma," beginning on page 668.

74 Achilles, *Isagoge in Arati Phaenomena*, 4; as quoted in G. S. Kirk, J. E. Raven and M. Schofield, trans. and eds., *The Presocratic Philosophers*, 2d ed. (Cambridge: Cambridge University Press, 1983), 29. This passage was quoted by Burnet.

75 These illustrations were used to schedule bloodlettings and other interventions for times of sympathy between the human microcosm and the appropriate aspects of the macrocosm. Cf. Harry Bober, "The Zodiacal Miniature of the Très Riches Heures of the Duke of Berry—Its Sources and Meaning," *Journal of the Warburg and Courtauld Institutes*, 1948, 11: 1–34 and Charles Clark, "The Zodiac Man in Medieval Medical Astrology," *Journal of the Rocky Mountain Medieval and Renaissance Association*, 1982, 3: 13–38.

and provided a sketch of the cosmos as an egg in his *Monas Hieroglyphica*.[76] Representations of Descartes' vortices appear somewhat egg-shaped, and ovoid paths of the planets were seriously entertained by Johannes Kepler before he settled upon ellipses as the trajectories of planets.[77]

Despite the promise of ancient testimony, Burnet's Cartesian universe of indefinite extent and seemingly endless vortices turns out not to be shaped like an egg. Therefore a nonliteral interpretation of the ancient image must be sought, Burnet believed, by which the three authorities (Reason, Scripture, and Antiquity) may be reconciled. Burnet hit upon a solution to this hermeneutical riddle by transfering the metaphor of the Mundane Egg from the figure of the universe to the figure of the Earth. Burnet regarded image transfer from the universe to the Earth as a "general key" to unlock the true meanings of a variety of ancient sayings about the world. Once this principle is granted, Burnet continued, "do but reflect upon our Theory of the Earth... and you will need no other interpreter to understand this mystery.... we have truly found out the Riddle of the Mundane Egg."[78]

In the Latin edition Burnet put his "general key" to work, showing to his satisfaction that ancient philosophers had regarded the Earth, rather than the universe, as an oval.[79] Even Moses silently hinted at the doctrine of the Mundane Egg, Burnet suggested, with the image in Genesis 1 of the Spirit hovering over the waters like a brooding bird, as if it were incubating the generation of the Earth from chaos like an egg.[80]

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[76] John Dee, *Monas Hieroglyphica* (Antwerp, 1564; reprint ed. and trans. C. H. Josten, Ambix, 1964, 12: 84-221).

[77] *Astronomia nova* (1609), chapters 44–55. Cf. *Johannes Kepler's New Astronomy*, trans. William H. Donahue (Cambridge: Cambridge University Press, 1992), 453.

[78] Burnet, 193. Cf. Burnet, *Telluris Theoria Sacra* (1681), 232.

[79] Cf. Book 2, chapter 10, a section entitled "Dein articulus quartus de Figurâ Telluris ovatâ authoritate Veterum munitur; ubi antiqua doctrina de Ovo Mundano digeritur, & perspicuè exponitur." Burnet, *Telluris Theoria Sacra* (1681), 277; cf. *Theory of the Earth* (rpt), 63. To show that this was the view of the Orphic philosophers, the Phoenicians, the Egyptians, and the Persians Burnet invoked a host of ancient writers, including Eusebius, Plutarch, Bacchicis, Athenagoras, Achilles Tatius, Aratus, Varro, Proclos, Plato, Zoroaster, Leucippus, Anaxagoras, Parmenides and Diodorus Siculus, repeatedly referring to Phoenician Theology. Burnet, *Telluris Theoria Sacra* (1681), 283.

Burnet aimed for concord between Reason (mainly Cartesian natural philosophy), Scripture (apocalyptically interpreted), and Antiquity (suitably decoded). "Reason is to be our first Guide," he wrote, since the Theory chiefly concerns philosophical rather than theological matters:

> This Theory being chiefly Philosophical, Reason is to be our first Guide; and where that falls short, or any other just occasion offers itself, we may receive further light and confirmation from the Sacred writings.... As for Antiquity and the Testimonies of the Ancients, we only make general reflections upon them, for illustration rather than proof of what we propose;....[81]

Moreover, the ancients wrote in a cryptic, prophetic mode, and therefore our interpretations of them are more error prone than either Reason or the didactic portions of scripture.[82] A proper Theory must be obtained before one can make intelligible the fragmented and puzzling statements of the ancients (or the obscure portions of scripture). Yet a unity of truth with the agreement of Reason, Scripture, and Antiquity should be possible if one has hit upon the correct Theory, and such a happy consilience was achieved with his solution to the riddle of the Mundane Egg:

> And considering that this notion of the Mundane Egg, or that the World was Oviform, hath been the sence and Language of all Antiquity, Latins, Greeks, Persians, Egyptians, and others . . . . Which being prov'd by Reason, the laws of Nature, and the motions of the Chaos; then attested by Antiquity, both as to the matter and form of it; and confirm'd by Sacred Writers, we may take it now for a well-established truth, and proceed upon this supposition....[83]

So powerful was the contemporary appeal of the Mundane Egg motif that one of the first Newtonian critics conceded Burnet's harmonization scheme. No less than William Whiston approved of Burnet's identification of the Earth with the Mundane Egg. While the Newto-

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[80] "Huic doctrinae de Ovo Mundano, dataeque interpretationi tacitè favere mihi videtur Incubatio Spiritûs Sancti in Abyssum, de quâ Moses in primâ telluris productione; ubi ad Ovum manifestò alluditur." Burnet, *Telluris Theoria Sacra* (1681), 286.

[81] Burnet, 26.

[82] "We will never depend wholly upon their credit, nor assert any thing upon the authority of the Ancients which is not first prov'd by natural Reason, or warranted by Scripture." Burnet, 25.

[83] Burnet, 63; cf. 196.

nian Whiston adamantly denied that the *figure* of the Earth was egg-like, he endorsed the ovoid analogy with the Earth's structure, notwithstanding the implicit Cartesian geogony, citing the same correspondences identified by Burnet.[84] Robert Hooke also envisioned an egg-like structure for the Earth. Like Burnet, Hooke gave considerable evidential value to ancient testimony critically deciphered.[85]

With solidification of the outer crust, Burnet explained that the globe had become a habitable world:

> Seeing this concrete Orb of Earth upon the face of the Water would be of the same form with the surface of the Water it was spread upon, there being no causes, that we know of, to make any inequality in it, we must conclude it equal and uniform, and without Mountains; as also without a Sea; for the Sea and all the mass of Waters was enclos'd within this exteriour Earth, which had no other basis or foundation to rest upon.[86]

With the series of global sections to this point Burnet has explained the stages through which the chaos became gradually transformed into a Paradisiacal world. The geogonic sections, taken together, have shown how one and the same globe could change in a gradual natural process from the first scene of the frontispiece into the second scene.

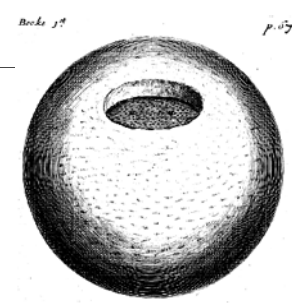

FIGURE 96. Smooth antediluvian globe. Book 1, chapter 6, p. 67. Burnet, *Theory of the Earth*, 1684. HSCI. (Repeat of Figure 86 on page 457.)

While the first chaos scene of the frontispiece may be regarded either as a global section or as a global view, the second frontispiece scene is definitely not a section, and Burnet reproduced something

[84] Whiston, 258–259. See Figure 165 on page 593 for one of Whiston's Burnetian-style ovoid-Earth diagrams.

[85] Robert Hooke, *The Posthumous Works of Robert Hooke... Containing his Cutlerian Lectures, and other Discourses, Read at the Meetings of the Illustrious Royal Society* (London: Publish'd by Richard Waller; Printed by Sam. Smith and Benj. Walford, 1705), 413. In his summary of the development of Hooke's views, Kubrin characterizes Hooke's reliance upon literary sources as an *Omnium in Verba* methodology in contrast to the alleged practice of the Royal Society according to their motto *Nullus in Verba*; Kubrin, "Providence and the Mechanical Philosophy," 152. See the discussion above, "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354.

[86] Burnet, 61.

like it as his next figure (Figure 96).[87] A global view cannot adequately illustrate this smooth Paradisiacal globe, Burnet continued: "Let us now close it up, and represent the Earth entire, and in larger proportions, more like an habitable World; as in this Figure, where you see the smooth convex of the Earth, and may imagine the great Abysse spread under it (as at the aperture *a.a.*);..."[88] In the diagram of the Paradisiacal world, the aperture is not a physical opening. Rather, it and the abyss beneath are made visible only to the eye of the mind, for the smooth outer surface of the globe is yet unbroken. The original 1681 Latin edition included

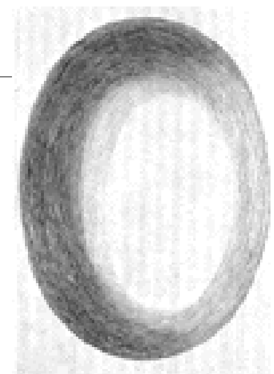

FIGURE 97. Oval global view of Paradise. Figure 6, Book 1, chapter 5, p. 30. Thomas Burnet, *Telluris Theoria Sacra,* 1681. HSCI.

Description. Rotated 90° to make Earth's axis vertical.

an ornamental global view of the egg-shaped antediluvian world with the aperture closed (Figure 97).[89] With either representation a global vision of a changing Earth has culminated with a portrait of the *surface* of the globe, visually concluding the geogonic series of whole-Earth *sections* with a different kind of illustration; *i.e.*, with a global surface view included not for the didactic purpose of conveying new information (as did the sections), but for enlisting the imagination as a "virtual witness" of the global changes already explained by the previous sectional diagrams.

The vision of the smooth Paradisiacal globe which Burnet cultivated to this point was apprehended with the eye of the imagination. Even were his Theory true, the Earth would

[87] Unlike the scenes of the frontispiece, which are global views, the geogonic series consists of global sections of the globe. Whether the chaos scene is a section or a view is ambiguous: it first served as a global section since the geogonic series predates the frontispiece, yet by appearance alone it may be interpreted as a global view like the other frontispiece globes.

[88] Burnet, 64.

[89] Burnet, *Telluris Theoria Sacra* (London, 1681). The Paradisiacal globe (Figure 96) first appears in the 1684 English edition, along with the frontispiece. The rest of the geogonic series was part of the original 1681 Latin edition, along with the alternative global view representing the ovoid Paradisiacal globe (Figure 97). The egg-shaped depiction of the Paradisiacal world is used instead of the globe in other editions as well, even when the frontispiece is included (e.g., Amsterdam, 1699).

not actually have looked this way to an observer viewing it from outer space. Because of the antediluvian water cycle, several distinct regions of the Earth would appear: the temporal zones, well-watered and suitable for habitation; the middle torrid equatorial zone, parched and dry; and the polar lakes (cf. Figure 95 on page 463). The torrid zone, in Burnet's opinion, did not detract from the global Paradise, but was like a gravel path running along the middle with green meadows lying on either side. Canals watered the garden from the extremes.

FIGURE 98. Peter Apian, Climatic zones. *Cosmographia* (1548). HSCI.

Ancient geographers from the time of Eratosthenes of Cyrene (third century B.C.) had divided the Earth into parallel bands or *klimata,* which were described in ancient encyclopedias such as Pliny's *Natural History* or Isidore of Seville's *Etymologies*. Burnet regarded the doctrine of the *klimata* as ancient corroboration for his Theory, since he believed the present Earth as seen from space would not display the climatic zones with sufficient clarity and distinctness to account for the wide acceptance of the idea. Before the Deluge, the Earth must have resembled a banded planet such as Jupiter, which even now may be in a Paradisiacal state. Burnet explained:

> the whole doctrine of the Zones is calculated more properly for the first Earth, than for the present; for the divisions and bounds of them now, are but arbitrary, being habitable all over, and having no visible distinction; whereas they were then determin'd by Nature, and the Globe of the Earth was really divided into so many Regions of a very different aspect and quality; which would have appear'd at a distance, if they had been lookt upon from the Clouds, or from the Moon, as Jupiter's Belts, or as so many Girdles or Swathing-bands about the body of the Earth.[90]

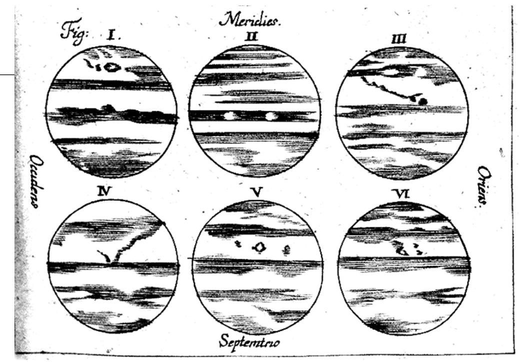

FIGURE 99. Bands of Jupiter, Cassini. Reprinted in the German edition of *Telluris Theoria Sacra*, 1703. HSCI.

The German edition of Burnet's Theory included Cassini's portrait of Jupiter (Figure 99). The bands of Jupiter offered an observable, heavenly analogue to a former terrestrial world not unlike the detail of Jupiter in Thomas Wright's *New Theory of the Universe* (1750) a half-century later (used on the epigraph page for Part II).[91] Jupiter's banded appearance was taken as corroboration of the Theory, in that it suggested the present existence of a planetary body in the paradisiacal state Burnet hypothesized.

In the Paradisiacal world the torrid zone was impassable. In effect, the northern and southern hemispheres were separate worlds, and for Burnet worlds were meant to be inhabited. Adam was the father of all humanity, and the discovery of the Americas proved that humanity was more widespread than previously believed (a conclusion that was corroborated by the companion discovery that American flora and fauna were often quite unlike their Old World counterparts). Given the impassable Torrid Zone of Burnet's Theory, how could the entire globe have become inhabited by descendents of Adam? Burnet anticipated this objection as a problem in moral history and therefore answered it with a miracle: "Providence seems to have made provision... in transplanting Adam into this [northern] Hemisphere, after he had laid the foundation of a World in the Other."[92] The entire globe was a single garden, thus Adam could have enjoyed both a southern and a northern home, each Paradisiacal. In Figure 95 on page 463 the four trees in the southern hemisphere apparently designate the initial location of Adam and Eve. The two trees in the northern hemisphere may represent the

90 Burnet, 192.

91 On Wright see footnote 2 on page 368.

92 Burnet, 194.

location to which Adam and Eve were miraculously translocated after initiating the human population of the south.[93] Before the Deluge the southern race spread to the regions that would become the New World. Thus Native Americans were descended from Adam, though not through Noah:

> I do not know that ever [the posterity of Noah] got into America till Columbus went thither in the last Age, who, for any thing I know, was the first of Noah's progeny that ever set foot in that Continent. Scripture tells us, that all Mankind rise from one Head, namely, from Adam, and his fault was derived to posterity, but no where that Noah was the common Head of Mankind that hath been since his time, nor does any doctrine of faith, that I know of, depend upon that supposition. When the great frame of the Earth broke at the Deluge, Providence foresee into how many Continents it would be divided after the ceasing of the Flood, and accordingly, as we may reasonably suppose, made provision to save a remnant in every Continent, that the race of Mankind might not be quite extinct in any of them.[94]

For Burnet the Deluge was physically universal, but not anthropologically universal—nor was it zoologically or botanically universal. Moses did not provide the full details of providence in this world any more than for the plurality of other worlds, and the details he did provide were subject to interpretation. Burnet concluded that his detractors' alternative supposition, *i.e.*, that life in the New World descended from Noachian stock, committed them to worse dilemmas: How did descendants of Noah overcome oceanic obstacles to east-west travel? And why were the New World flora and fauna so unlike that of the Old, if they too were related by descent? Moreover, Burnet's position avoided polygenic Pre-Adamism with its opprobrium, although he interpreted apocalyptic prophecies as implying rebellious human polygenism in the millennium, and regarded interracial or polygenic interbreeding as the offense which provoked the Deluge.[95]

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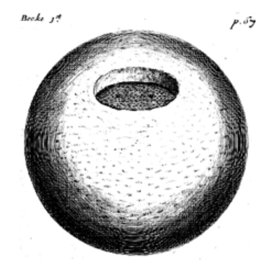
93 This is speculation inferred from the text; the first Latin edition does not contain this diagram, and no edition explicitly mentions the trees.

94 Burnet, 195. Cf. pp. 196, 375, 139.

§ 5. Crustal Collapse: The Early Modern Platonic Paradigm



The “cut away” view of the Abyss afforded by Burnet’s illustration of the Paradisiacal globe (Figure 96 on page 469) portends that the idyllic world on the habitable surface could not last, but at some point would collapse upon the Abyss and undergo cataclysmic changes leading to the next two scenes of the frontispiece. In the text accompanying the illustration Burnet sketched out these revolutions, verbally describing the onset of the universal deluge and the resulting brokenness of the present Earth:

> Let us then suppose, that at a time appointed by Divine Providence, and from Causes made ready to do that great execution upon a sinful World, that this Abysse was open’d, or that the frame of the Earth broke and fell down into the Great Abysse. At this one stroke all Nature would be chang’d, and this single action would have two great and visible Effects. The one transient, and the other permanent. First an universal Deluge would overflow all the parts and Regions of the broken Earth, during the great commotion and agitation of the Abysse, by the violent fall of the Earth into it. This would be the first and unquestionable effect of this dissolution, and all that World would be destroyed. Then when the agitation of the Abysse was asswag’d, and the Waters by degrees were retir’d into their Chanels, and the dry land appear’d, you would see the true image of the present Earth in the ruines of the first.[96]

During a foreordained period of time, by the drying and evaporative actions of the heat of the Sun, the primeval crust became cracked and brittle while, simultaneously, vapours of the Abyss applied upward pressure from below. Finally, at one great stroke in the fullness of time the crust broke open and collapsed. This singular “Turn of Fate” was one of the great “Hinges” of which Burnet had spoken, “upon which the Providence of this Earth moves . . . whereby it opens and shuts the several successive Scenes.”[97]

[95] The question whether humans lived before Adam was brought to the fore by Isaac de la Peyrère (1596–1676) and was never remote from commentaries on Genesis (where it had been espoused by Philo) or the Theory of the Earth tradition. On Preadamism generally see Richard H. Popkin, *Isaac La Peyrère (1596-1676), his Life, Work and Influence* (Leiden, 1987); Anthony Grafton, *Defenders of the Text*, chapter 8; and two articles by David N. Livingstone: “Preadamite Theory and the Marriage of Science and Religion,” *Transactions of the American Philosophical Society* 82 (1992), Part 3 in its entirety, and “Preadamites: The History of an Idea from Heresy to Orthodoxy,” *Scottish Journal of Theology* 40 (1987): 41-66.

[96] Burnet, 65–66.

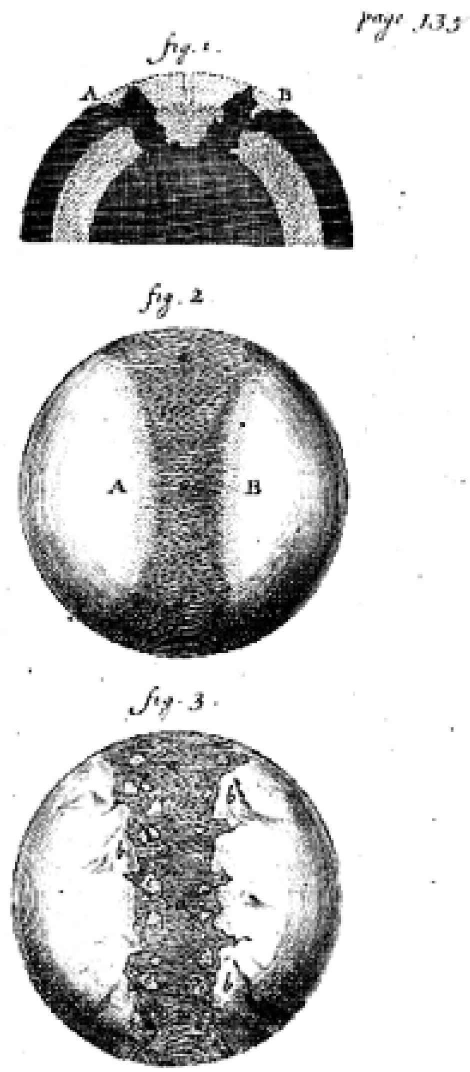


FIGURE 100. Crustal Collapse trio of figures. Book 1, chapter 6, p. 125. Burnet, *Theory of the Earth*, 1684. HSCI.

Burnet adapted this figure of speech to figures of sight in a literal sense, drawing fragments of the opened crust as if they were hinged and had swung downward into the abyss. This occurs in a series of three diagrams combining one global section with two global views (Figure 100):

> This we have represented here only in a Ring or Circle of the Earth, in the first Figure; but it may be better represented in a broader surface, as in the second Figure, where the two fragments A. B. that are to make the two opposite Continents, fall in like double Doors opening downwards, the Hinges being towards the Land on either side, so as at the bottom they leave in the middle betwixt them a deep Chanel of water, a. a. a. such as is betwixt all Continents; and the Water reaching a good height upon the Land on either side, makes Sea there too, but shallower, and by degrees you descend into the deepest Chanel.[98]

[97] Burnet, 15. Quoted in full context on page 433 of this chapter.

[98] Burnet, 107. These diagrams first appear in the 1684 English edition.

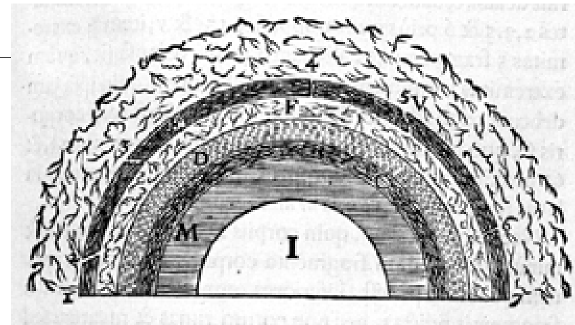


FIGURE 101. First global hemisection. Descartes, *Principiae philosophiae*, 1644. LH.

Consider first Burnet's sectional "Circle of the Earth" depicting the crustal collapse (the first figure of the trio). Again Burnet has appropriated a Cartesian visual model (Figure 101). This first of two related Cartesian figures resembles the last quadrant of the comet-to-planet "wheel of time" examined above (Figure 89 on page 459), except for the presence of a new layer, F. According to Descartes, after "many days and years," a great part of the watery abyss D, rarefied by the light and heat of the Sun, escaped through pores in the outer crust E and left a hollow space F underneath that could be filled only by the smaller particles of the airy region B. Because of its hardness, the crust E "remained suspended for a time above D and F like a vault."[99] Great fissures in the crust E developed over time "for exactly the same reason that many cracks appear in the earth when it is dried out by the Sun in the summer."[100] The fissures are depicted at points 1–7 in Figure 101. When did this occur? Burnet claimed originality in tying these events to the Deluge, for Descartes did not specify when they occurred and, as we shall see, other Cartesians regarded them as part of the creation week.

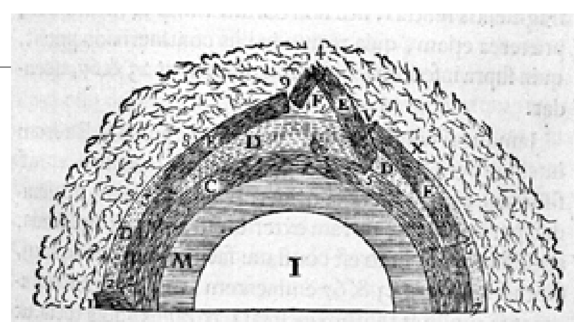


FIGURE 102. Second global hemisection. Descartes, *Principia philosophiae*, 1644. LH.

For Descartes, a succession of violent events quickly followed one another. Crust E, "entirely broken, fell by its own

[99] *Principia Philosophiae* Part IV, Articles 40–41; Descartes, 200–201.
[100] *Principia Philosophiae* Part IV, Article 41; Descartes, 202.

weight onto the surface of body C" (the interior crust beneath the abyss).[101] This is illustrated in Descartes' second global hemisection (Figure 102), where crustal fragments 2–3 and 6–7 have collapsed to form ocean beds. Point 1 represents cliffs or islands on the shores of an ocean. A lofty mountain has been raised at 4, a less elevated one at 9.

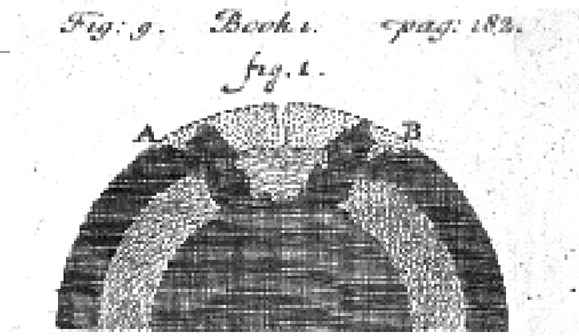


FIGURE 103. Burnet's global hemisection. *Theory of the Earth*, 1684. Book 1, chapter 6, p. 125. HSCI.

Burnet clearly followed Descartes' account of the vaulted crust in his verbal description of the Orb of the Earth, suspended like an arch over the abyss. Similarly, Burnet employed Descartes' mechanism of crustal fissures, resulting from the same two-fold effects of the Sun (crustal drying and the rising of vapors). In abstract form, Burnet's global hemisection recalls the two of Descartes. The diagram of Burnet shows the original crust in light hatching, including a central fissure reminiscent of fissure 4 in Descartes' first figure. In effect, Burnet's diagram then overlays Descartes' second figure upon the first, portraying the now-collapsed crust in darker hatching as having formed an ocean bed with adjacent island peaks. Compared to Descartes' sections, the visual appeal of Burnet's diagram is made more effective by reducing the degree of abstraction (the edges of the tilted fragments are not drawn geometrically, but unevenly by freehand) and by simplifying details (there are fewer labels). These stylistic features of Burnet's hemisection make more evident and immediately recognizable the correspondences of particular details (e.g., the tops of the "hinges") to their referents in the actual Earth (e.g., islands along the edges of continents).

[101] *Principia Philosophiae* Part IV, Article 42; Descartes, 202.

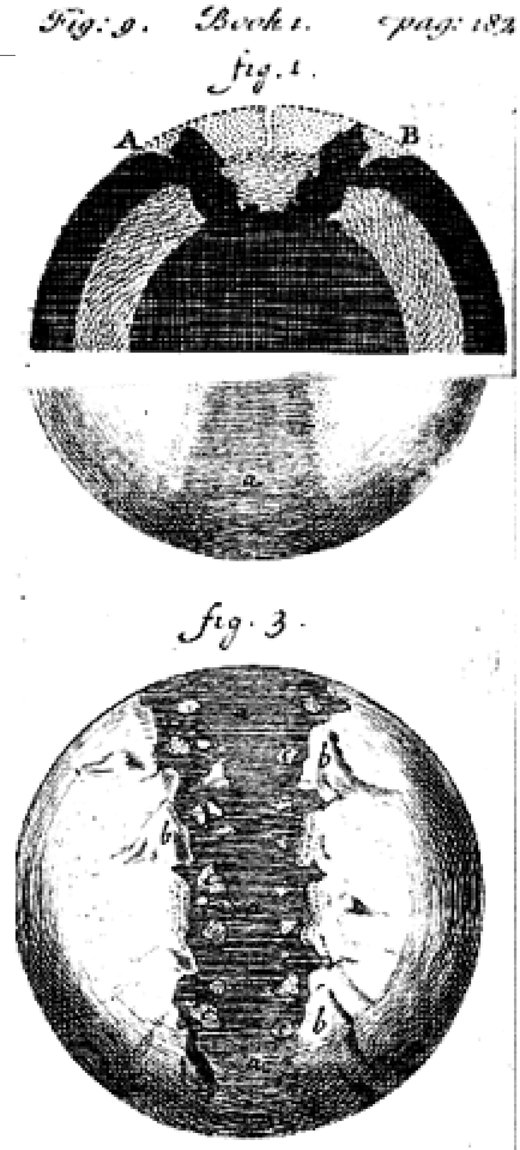


FIGURE 104. Collapse trio (Figure 100), folded.

With the compact two-in-one section Burnet made room on the same page for two global views. Burnet's evidential (not just didactic) use of global views moves the imagination in a more concrete and familiar direction, in the mind's eye linking the previous section with the actual Earth in a compelling and recognizable way. Note that shallow waters along the continental shores are depicted (middle figure; compare Figure 100) along with coastal cliffs and island chains (bottom figure).

An instructive contrast is to examine the islands as depicted in Burnet's *figure 3* and *figure 1*, and then look for island chains or coastal cliffs in Descartes' second hemisection. Descartes' sections are abstracted to the point of obscuring their correlations with the actual Earth. It is striking that Descartes' verbal account reflects the extreme abstraction of his diagrams, for he only revealed the correspondences with the actual Earth after the processes depicted by his diagrams were derived by deduction from first causes. Such a delayed recognition of correspondences may produce an unexpected "aha!" discovery experience in the reader; therefore Descartes' diagrammatic abstraction constitutes a visual rhetoric consistent with his overall verbal strategy of insisting that everything is derived in a causal account through pure reasoning from first principles. Burnet's Theory and rhetoric are quite different. The extent of Burnet's visual transformation of Descartes is seen in the fact that even Burnet's hemisection, despite its abstraction, retains a connection with the actual Earth heightened by the companion global views. The 1726 edition accentuated the correspondences between these diagrams with a pull-out version of the page that folded to align the global hemisection with one of the global views (Figure 104).

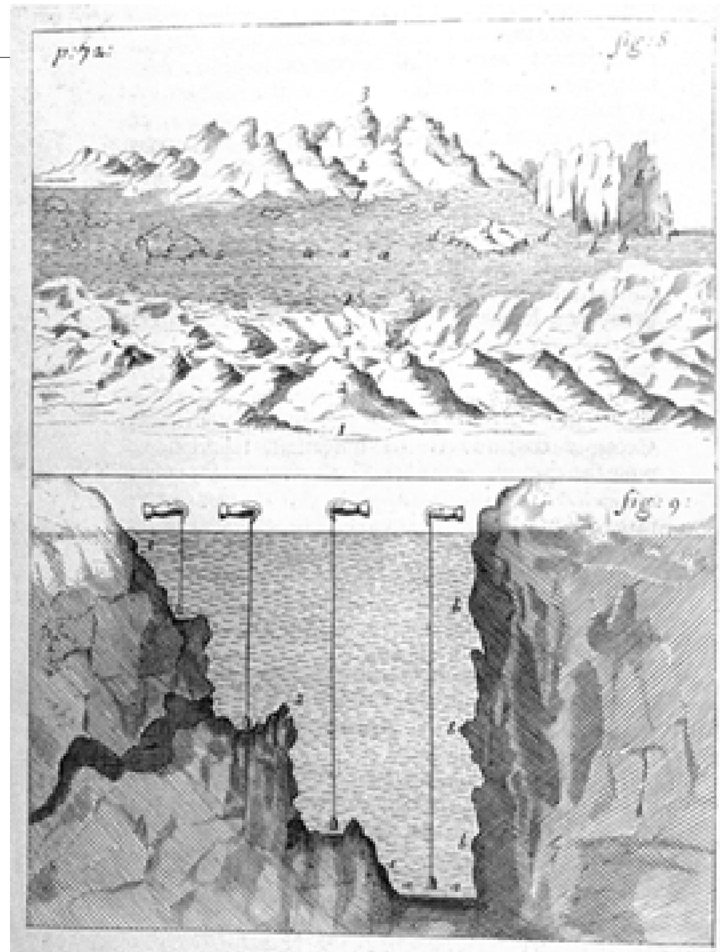


FIGURE 105. Shoreline section and view. Burnet, *Telluris Theoria Sacra*, 1681. Book 1, chapter 6, p. 72, figures 8 and 9.

In the original 1681 Latin edition, Burnet depicted the crustal collapse with a pair of evidential illustrations drawn on a regional rather than global scale. A landscape view (*figure 8*) shows the topography of an ocean channel scene. An ideal regional section (*figure 9*) correlates the submarine contours with the surface topography (Figure 105; compare Table 52). Various labels correlate these regional depictions: *a,* the abyss or depths of a deep ocean channel; *b,* perpendicular cliffs or fjord-like shorelines; *c,* submarine islands or submerged mountains; *d*, islands which emerge from the water; *e*, lowlands between mountain chains; and *1, 2, 3*, coastal and continental mountain chains. In response to a combination of visual images, masterfully conducted to emphasize sensible qualities and alleged empirical evidences, the imagination becomes a virtual witness of Burnet's Theory.

TABLE 52. Shoreline depths: Two other Evidential Illustrations

FIGURE 106. Kircher, *Mundus subterraneus*, 98.

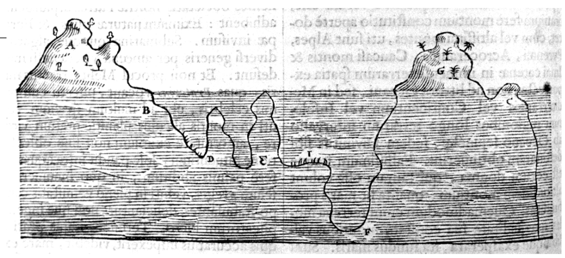
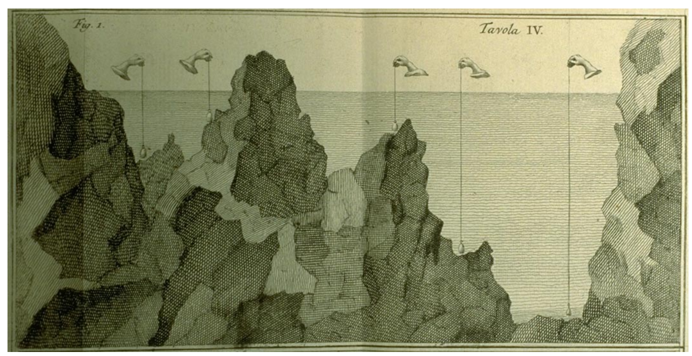


FIGURE 107. Moro (from Burnet)



§ 6. Theological Controversy: A Global Deluge

Upon the collapse of the crust there results a scene of watery destruction. We have already noted that the frontispiece view of Paradise was redrawn for the text. It is the same with the next two scenes as well: both the Deluge and the present Earth are redrawn and enlarged at key passages in the text. Burnet confessed that "'tis not easie to represent to our selves this strange scene of things," although his prose waxes almost Miltonic in the effort:

> When the Deluge was in its fury and extremity; when the Earth was broken and swallow'd up in the Abysse, whose raging waters rise higher than the Mountains, and fill'd the Air with broken waves, with an universal mist, and with thick darkness, so as Nature seem'd to be in a second Chaos; and upon this Chaos rid the distrest Ark, that bore the small remains of Mankind. No Sea was ever so tumultuous as this, nor is there any thing in present Nature to be compar'd with the disorder of these waters; All the Poetry, and all the Hyperboles that are us'd in the description of Storms and raging Seas, were literally true in this, if not beneath it.[102]

This situation merited prolonged reflection, so Burnet provided an ornamental icon for the reader's contemplation: "We may entertain our selves with the consideration of the face of the Deluge, and of the broken and drown'd Earth, in this Scheme, with the floating Ark, and the guardian Angels."[103]

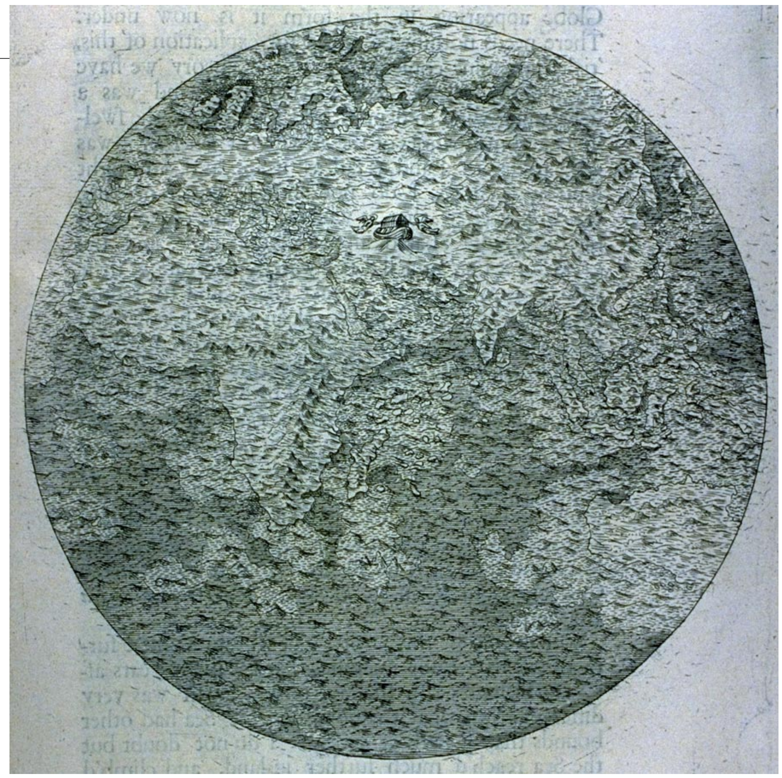


FIGURE 108. Burnet's deluge. *Theory of the Earth*, 1684.

Burnet's global view of the Deluge is neither a naturalistic portrait nor a geographic map. Although the waves are depicted by the nonnaturalistic symbols used on conventional maps, the waterscape as a whole is not a mere symbol, like the sceptre representing Christendom. Nor does it convey new information, phenomena, or evidence in a nonverbal form. Burnet's depiction of the global deluge is ornamental rather than didactic, and dramatically countered rising suspicions that the deluge had been only regional in extent. Orthodox scholars such as the librarian to the Queen of Sweden Isaac Voss (1618–1689), the Bishop of Worcester Edward Stillingfleet (1635–1699), the Nonconformist commentator Matthew Poole (1624–1679), as well as the more notorious Isaac de la Peyrère (1596–1676),

[102] Burnet, 84.

[103] Burnet, 84. The Deluge illustration first appears in the 1684 English edition, along with the frontispiece. Upon viewing this global scene, modern readers are likely to "entertain our selves" in a manner not entirely anticipated by Burnet.

are typical of a growing minority who argued for a limited extent of the deluge. They accepted a regional deluge largely because of biogeographical evidence from the New World, often arguing for merely an anthropologically-universal catastrophe, assuming that humans did not spread so far as animals in the antediluvian world. Defenders of a global deluge found it necessary continually to update calculations of the capacity of the Ark to show that it could hold all of the animal species known to a rapidly-expanding global natural history. As we have seen, Burnet had a different explanation for New World flora and fauna, so he had no need to devote himself to defending the capacity of the Ark. Although persuaded that Native Americans were not descended from Noah, he had no desire to adopt the restricted deluge of the preAdamists. Burnet's ornamental global view memorably and effectively affirms the reality of the global deluge as a singular and extraordinary event.[104]

Although modern commentators rightly emphasize that Burnet's explanation of the deluge relied upon predictable natural causes, the most noticable feature of Burnet's global view of the deluge is Noah's ark. Like the waves surrounding it, the ark itself is depicted in a highly symbolic manner, and is likely to be regarded by the modern reader as a quaint curiosity. But why should particular attention be directed to the ark in this scene of the globe?[105] Burnet offers explicit reasons in the text, and they are no more naturalistic than the stylized conventions employed in the visual depiction. The reason for the oversize ark has to do with the symbolic meaning of the two angels which attend it:

> We may with more reason suppose the good Angels to have lookt down upon this Ship of Noah's; and that not out of curiosity, as idle spectators, but with a passionate concern for its safety and deliverance. A Ship whose Cargo was no less than a whole World; that carri'd the fortune and hopes of all posterity, and if this had

[104] On de la Peyrère and Preadamism see footnote 95 on page 474. On controversies over the extent of the deluge and the capacity of Noah's Ark see the references cited in footnote 139 on page 73. A clear discussion is Davis A. Young, *The Biblical Flood: A Case Study of the Church's Response to Extrabiblical Evidence* (Grand Rapids: Eerdmans, 1995), chapter 4, "The Impact of the Exploration of the New World."

[105] A similar question about Buffon's rhetorical use of ornamental illustrations was asked in "Ornamental Global Views in Buffon's Histoire naturelle," beginning on page 379.

> perisht, the Earth, for any thing we know, had been nothing but a Desert, a great ruine, a dead heap of Rubbish, from the Deluge to the Conflagration. But Death and Hell, the Grave, and Destruction have their bounds. We may entertain our selves with the consideration of the face of the Deluge, and . . . the guardian Angels.[106]

The angels symbolize the particular providential interposition of supernatural agency in the moral world. The particular providence manifest in the attendant angels protecting the ark, keeping it from being "dasht against the hills," injects a contingent element into an otherwise causal account of general providence. From a natural standpoint, it was virtually certain that the ark would not survive:

> It was no doubt an extraordinary and miraculous Providence, that could make a Vessel, so ill man'd, live upon such a Sea; that kept it from being dasht against the Hills, or overwhelm'd in the Deeps. That Abysse which had devour'd and swallow'd up whole Forests of Woods, Cities, and Provinces, nay the whole Earth, when it had conquer'd all, and triumph'd over all, could not destroy this single Ship.[107]

Through particular providence a singular and unique event, which could not have been predicted on the basis of natural laws and is not likely ever to be repeated, has superadded the contingent character of historical drama onto general providence expressed in the ordinary course of nature. In this way particular providence could be invoked to explain the outcome of historical events, although in Burnet's case particular providence served the ends of redemptive history rather than explaining the general providence governing the natural world. The anomalous character of the Deluge results from the conjunction in the same event of historical particular providence and natural general providence.

Why was it important to Burnet at this point to emphasize the particular providence accompanying the Deluge? Despite his frequent references to natural causes as merely instruments of God's general providence, Burnet's reliance upon a natural mechanism for the Deluge made him vulnerable to accusations of having practically denied the rule of God in the

[106] Burnet, 84.
[107] Burnet, 84.

world. Burnet's Theory proposed that God, through general rather than extraordinary providence, ordained from the beginning the crustal collapse and universal Deluge, and to his critics it took on a semblance of physical necessity. The traditional doctrine of general providence did affirm that the Creator governs his creation by means of the ordinary course of nature, a natural order which reflects his faithfulness and was freely ordained by his creative decree. But for a clergyman writing for a general audience, in a philosophical treatise dedicated to tracing out the natural causes of things, it was important to demonstrate that affirmations about general providence were not the dissimulations of a closet deist. To talk of general providence alone was not enough; any deist could do as much. To emphasize particular and special providences, on the other hand, as effectively certified one's orthodox credentials as to proclaim allegiance to traditional Christology (which Burnet already skillfully had done in the frontispiece). The visual message of this scene, then, is a commonplace of Reformed theology, the constant mutual coordination of general and particular acts of providence.[108] The natural world, the moral world, and the particular interpositions of supernatural agency march together in time. Without this affirmation of particular providence in the course of human history Burnet's orthodoxy would have been suspect from the beginning. With it many theological critiques might be deflected, despite the relegation of the natural order—the development of the Earth apart from redemptive history—to general providence alone. However, in response to past problems with Cartesianism and the almost immediate appropriation of Burnet's Theory by English deists such as Charles Blount, some theological critics insisted upon the necessary agency of particular providence in the natural realm to account for the physical onset of the Deluge as an event outside the ordinary course of nature, and they were not per-

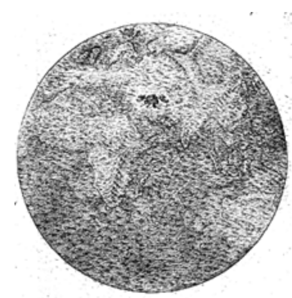
[108]James Moore has called the legitimization of autonomous theorizing in the natural sciences, so long as natural scientists were willing to affirm that their conclusions glorified God by revealing the wisdom of the Creator, the "Baconian compromise." See James R. Moore, "Geologists and Interpreters of Genesis in the Nineteenth Century," in *God and Nature: Historical Essays on the Encounter between Christianity and Science*, ed. David C. Lindberg and Ronald L. Numbers, 322–350 (Berkeley: University of California Press, 1986). Similarly, we may call this legitimation of speculation regarding the natural causes of historical events by the simultaneous affirmation of particular providences the "Puritan compromise."

suaded by Burnet's affirmations.[109] The significance of views of particular providence in the development of attitudes regarding natural order and historical contingency often has been overlooked, especially in previous discussions of providentialist geology that have emphasized general providence almost exclusively.[110]

[109]See Chapter 8, "The Idiosyncrasy of Burnet" and especially "Blount, Burnet, and the Oracles of Reason, 1695," beginning on page 502." Bishop Herbert Croft was typical in seeking a greater role for particular than general providence in the Deluge: "for I suppose he will stick to his own method of having Natural Causes for all things, and will not allow God the liberty to use any extraordinary means, tho upon such an extraordinary occasion as the Deluge or Conflagration." Croft quipped that Burnet himself is a miracle if he can allow no miracle in the deluge, warning: "Mark you now: This Man would not allow God to do the least Miracle to make good the common interpretation of Moses's words; no, by no means, he must not alter the course of Nature." The special providence and miraculous preservation of the ark did not satisfy Croft: "the preservation of it must be a far greater Miracle, than any we require in Moses's Deluge. And thus is that Chapter framed in so wonderful a Romantick way, as exceeds all that ever yet was written of that kind." Cf. Herbert Croft, Bishop of Hereford, *Some Animadversions Upon a Book Intituled the Theory of the Earth* (London: Printed for Charles Harper, 1685), 39, 75, 88, 123, and 125–126.

[110]The doctrine of particular providence continued to play a dynamic role in the Theory of the Earth tradition into the nineteenth century (Whewell), but is almost ignored by Gillispie, *Genesis and Geology*, who nevertheless offers an admirable account of the interactions between geological theorizing and doctrinal and ideological traditions of general providence. Cf. Charles Coulston Gillispie, *Genesis and Geology: A Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790–1850* (Cambridge: Harvard University Press, 1951).

§ 7. The Natural Face of a Wrecked and Ruined World



Even as the guardian angels shepherd the ark to its resting place upon the mountain of Ararat, the shape of the present world can be discerned beneath the diluvial waters. Continental outlines reveal the eastern hemisphere of a new world, i.e., the present wreck of a world emerging from the old world's destruction as the waters recede. One can even spot mountain ranges, that novel feature of the new world, which must have threatened the ark with destruction were it not for the attendant angels. To obtain the present state of the Earth from the scene of the general Deluge it was only necessary for the waters to abate. To illustrate the present Earth Burnet included

FIGURE 109. Eastern hemisphere. Burnet, *Telluris Theoria Sacra*, 1681. Book 1, chapter 6, p. 72, figure 8. HSCI.

a striking two-part "Map or Draught of the Earth." The first map represents a scene from the frontispiece, but it has been enhanced in visual significance not only by being redrawn in larger form than the cameo version but by the accompanying representation of the western hemisphere (Figure 109 and Figure 110).[111] Both hemispheres are depicted in the manner of geographical maps of the world. Areas of *terra incognita* are noted. Using contemporary cartographical conventions, the mountain ranges are depicted with molehill symbols.[112] Almost never does a single molehill correspond to a particular

[111]These hemisphere maps appeared in the 1681 Latin edition, and were simply reprinted, in the same size, for the 1684 English edition.

actual mountain; Ararat is not specified, for instance, as it was on the depiction of the Deluge.[113]

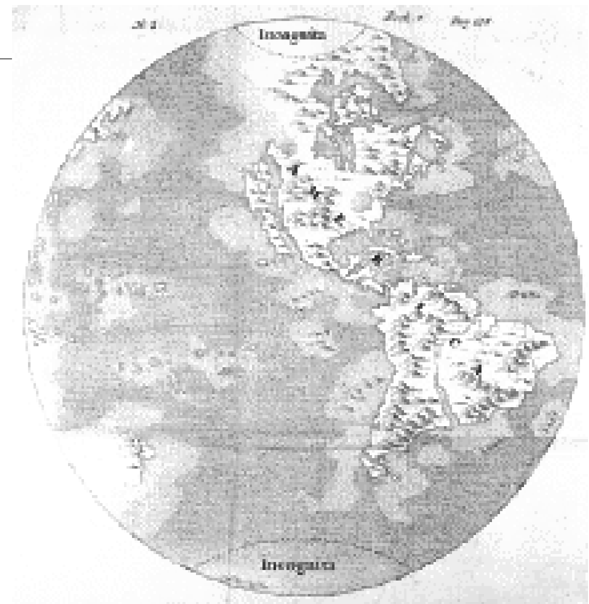


FIGURE 110. Western hemisphere. Burnet, *Telluris Theoria Sacra*, 1681. HSCI.

While owing much to the visual conventions of geographical cartography, Burnet's maps differ in several respects. In the oceanic areas a lighter hatching seems to depict shallower continental coastal areas with their scattered islands, and a darker hatching represents deeper ocean channels (consonant with the illustrations of the collapse as described above). The geographers' world maps tend to show the outlines of continents and the courses of rivers but not the topography of the land. For example, mountain ranges are frequently omitted to make room for labels of countries, towns, and other civil

[112]Consider Rudwick's perceptive comments on early topographical maps; "Visual Language," 159–160: "Until the early nineteenth century the surveys on which maps of even the culturally central areas of Western Europe were based were poor or mediocre, and no geological map could be better than the topographical map that served as its base. Furthermore, even when these surveys improved in quality, as they did first in France and later in Britain and other countries, the available cartographic conventions were ill-adapted for the accurate portrayal of the physical topography that was so important for geological interpretation. De Saussure was only able to illustrate the Alpine topography of the Mont Blanc region by a map on which the mountains are represented by the ancient and crude cartographic convention of 'mole hills'. Even the best surveys, despite detailed information about the positions of towns and villages and the courses of streams and rivers, were only able to indicate the configuration of the hills by a crude form of hachuring, which gives a generally deceptive impression of the topography. It makes the valleys look like steep-sided trenches cut into a flat plateau, and it makes higher hills look as though they are built up in a series of terraces. It is difficult to over-emphasize the extent to which these cartographic limitations impeded the use of maps as a medium for the communication of complex and abstract forms of geological information."

[113]For historical struggles with the vexed question of the Ark's present resting place, a topic common to ancient commentaries on Genesis, sacred geographies, and many Theories of the Earth (though not Burnet's) see Lloyd R. Bailey, *Where is Noah's Ark?* (Nashville: Abingdon, 1978); Lloyd R. Bailey, *Noah: The Person and the Story in History and Tradition*, Studies on Personalities of the Old Testament, ed. James L. Crenshaw (Columbia: University of South Carolina Press, 1989); Jack P. Lewis, *A Study of the Interpretation of Noah and the Flood in Jewish and Christian Literature* (Leiden: E. J. Brill, 1968); Eugene S. McCartney, "Noah's Ark and the Flood: A Study in Patristic Literature and Modern Folklore," *Papers of the Michigan Academy of Science, Arts, and Letters*, 1932, 18: 71–100.

entities, though they are a chief feature of Burnet's depictions: "'Tis chiefly to expose more to view the Mountains of the Earth, and the proportions of Sea and Land, to shew it as it lies in it self, and as a Naturalist ought to conceive and consider it."[114]

To overcome particular biases common to lowland-dwelling Englishmen, since "'Tis certain that we naturally imagine the surface of the Earth much more regular than it is...,"[115] Burnet provided a verbal tour of the principal mountain ranges that mar the surface of each hemisphere. Although unfamiliar to the experience of many of his English readers, he impressed upon them that mountains occupy a full one-tenth of the dry land:

> I have given this short account of the Mountains of the Earth, to help to remove that prejudice we are apt to have, or that conceit, That the present Earth is regularly form'd. And to this purpose I do not doubt but that it would be of very good use to have natural Maps of the Earth, as we noted before, as well as civil; and done with the same care and judgment. Our common Maps I call Civil, which note the distinction of Countries and of Cities, and represent the Artificial Earth as inhabited and cultivated: But natural Maps leave out all that, and represent the Earth as it would be if there was not an Inhabitant upon it, nor ever had been; the Skeleton of the Earth, as I may so say, with the site of all its parts.[116]

Although misshapen, the Earth is a natural, not artificial body, and as such requires a model "Skeleton of the Earth" to give its physician the sight "of all its parts."[117] Geographers, Burnet charged, observed the garments or artificial aspects of the world, devoting insufficient care to the natural body, unlike philosophers who would be true anatomists of the Earth:

> The Geographers are not very careful to describe or note in their Charts, the multitude or situation of Mountains; They mark the bounds of Countries, the site of Cities and Towns, and the course of Rivers, because these are things of chief use to civil affairs and commerce, and that they design to serve, and not Philosophy or Natural History. But Cluverius in his description of Ancient Germany, Switzer-

[114]Burnet, 118.

[115]Burnet, 110.

[116]Burnet, 112.

[117]Burnet remarks: "'tis very useful to imagine the Earth in this manner, and to look often upon such bare draughts as shew us Nature undrest; for then we are best able to judge what her true shapes and proportions are." Burnet, 110. On the gender implications of the metaphor of nature undressed in early modern science see Carolyn Merchant, *The Death of Nature: Women, Ecology, and the Scientific Revolution* (San Francisco: Harper and Row, 1979); idem, "Isis' Consciousness Raised," *Isis*, 1982 (73): 398-409.

land, and Italy, hath given Maps of those Countries more approaching to the natural face of them, and we have drawn (at the end of this Chapter) such a Map of either Hemisphere, without marking Countries or Towns, or any such artificial things; distinguishing only Land and Sea, Islands and Continents, Mountains and not Mountains...[118]

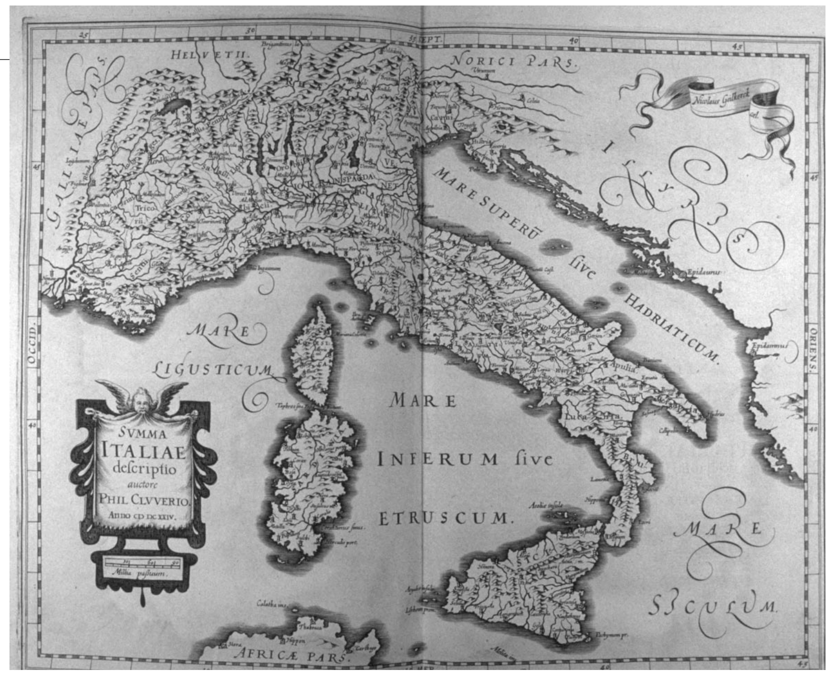


FIGURE 111. Clüver. *Italia antiqua* (1624). HSCI.

In his ancient geographies, Philipp Clüver (1580–1622) stripped away the layers of later civilization to reveal more of the natural face of the land (Figure 111).[119]

Clüver's natural maps were national and regional, while Burnet advocated drawing up the portrait of the Earth on a global scale.[120] Burnet provided a natural map of the globe in two hemispheres executed in a highly conventional cartographic manner but with artificial civil characters stripped away. To do so, visual conventions were available not only from geography, but also from cosmography and cosmology. For example, Burnet's contemporary Fontenelle wrote of telescopic observers of the Moon, that they were "so well acquainted with the

[118] Burnet, 110.

[119] Philipp Clüver, *Italia Antiqva; Opus post omnium curas elaboratissimum; tabulis geographicis aere expressis illustratum*, 2 vols. (Lvgdvni Batavorvm; ex officina Elseviriana, 1624).

[120] Burnet did not depreciate regional natural history maps: "Methinks also every Prince should have such a Draught of his own Country and Dominions, to see how the ground lies in the several parts of them, which highest, which lowest; what respect they have to one another, and to the Sea; how the Rivers flow, and why; how the Mountains stand, how the Heaths, and how the Marches are plac'd. Such a Map or Survey would be useful both in time of War and Peace, and many good observations might be made by it, not only as to Natural History and Philosophy, but also in order to the perfect improvement of a Countrey." Burnet, 112.

several parts that they have given them all Names . . . in short, they have published such exact descriptions of the Moon, that a very Almanac-maker who found himself there nowadays could go no more astray than I could in Paris."[121] In the *Somnium* Kepler considered how the the Earth and other planets would appear from the Moon, describing the large-scale features of both the eastern and western hemispheres.[122] William Gilbert's map of the Moon followed the naming conventions of Ptolemy's *Geography*, employing descriptive terms such as

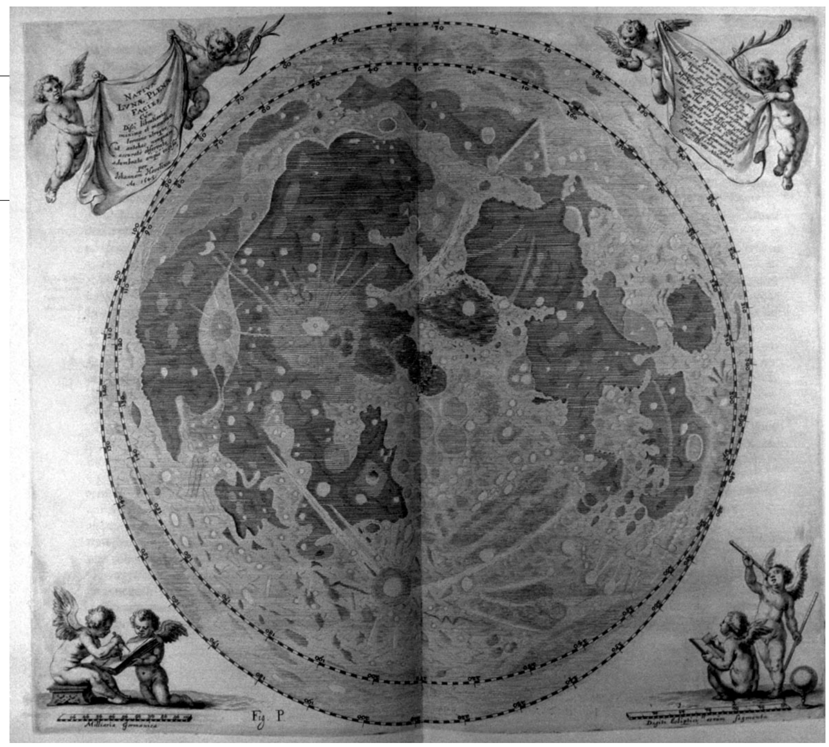


FIGURE 112. Hevelius, Fig. P, *Selenographia* (1647). HSCI.

Description. Composite face of the Moon.

sinus (bay), *regio* (great), *mare* (ocean), *insula* (island), or *borealis* (northern).[123] Galileo depicted the rough, cratery surface of the Moon in 1610. Three decades

[121]Fontenelle, Second Evening, 49–50, translation slightly altered.

[122]Kepler described the Earth (Volva) as it would appear to inhabitants of the near side of the Moon (Subvolvans): "For even though it does not seem to have any motion in space, nevertheless, unlike our moon, it rotates in place and displays in turn a wonderful variety of spots, as these spots move constantly from east to west. One such revolution, in which the spots return, is regarded by the Subvolvans as one hour of time; it is equal, however, to a little more than one of our days added to one of our nights. This is the only uniform measure of time. For, as was pointed out above, the sun and stars move non-uniformly about the moon-dwellers every day." Johannes Kepler, *Somnium: The Dream, or Posthumous Work on Lunar Astronomy*, trans. and ed. Edward Rosen (1634; Madison: University of Wisconsin Press, 1967), 23–24; cf. Montgomery, *The Moon*, ch. 9, esp. 140–143. For a similar quote from Frances Godwin, see page 401.

[123]The lunar map in Gilbert's *De mundo* was posthumously published in 1651, but it was previously seen in manuscript by others, including Francis Bacon and Thomas Harriot. Scott Montgomery suggests that "Ptolemy had an equal or greater influence over conceptions of the Moon through his writings on terrestrial geography." Scott L. Montgomery, *The Moon and the Western Imagination* (Tucson: University of Arizona Press, 1999), 104.

later, the *Selenographia sive lunae descripto* (1647) of Johannes Hevelius (1611–1687) contained 134 engravings, including forty different figures of lunar phases (Figure 112). In the words of Winkler and Van Helden, "Hevelius' intent was programmatic. The title of the book announces that it is to be a description of the moon, that it contains an accurate sketch (*delineatio*) of that body, and that it also shows the natural appearances (*nativa facies*) of the planets and the sun."[124] Montgomery remarks that "a readiness to see the Earth itself in a new light—this is what the vision of the Moon, as a planet with a true geographical surface, offered."[125]

Burnet declared that he would map the Earth as a cosmologist mapped the Moon, i.e., according to its natural face rather than an artificial state; and in its entirety as another world rather than with the limited features of a familiar locality:

> To conclude both this Chapter and this Section, we have here added a Map or Draught of the Earth, according to the Natural face of it, as it would appear from the Moon, if we were a little nearer to her; or as it was at first after the Deluge, before Cities were built, distinctions of Countries made, or any alterations by humane industry.[126]

Just as plausibly as we may observe the Moon, so might a lunar observers witness the globe of the Earth in the natural states portrayed in Burnet's Theory. Through Burnet's visual rhetoric the present state of the Earth literally becomes another world to the imagination, a global vision, as if we were transported to the Moon to view it entire.[127]

Yet Burnet argued that techniques of representation needed to go a step further than his natural portrait of the Earth. A global vision in two flat dimensions would still be too abstract, even if the Earth were drawn by a lunar-dwelling Hevelius. Burnet urged those who

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[124]Mary G. Winkler and Albert Van Helden, "Representing the Heavens: Galileo and Visual Astronomy," *Isis*, 1992, 83: 195–217, on p. 217. Hereafter "Winkler and Van Helden."

[125]Montgomery, *The Moon*, 145–146. Montgomery explores how the Moon long served in western culture as the alter-ego of the Earth, as conceptions of the terrestrial world were inscribed upon the Moon before more well-known seventeenth-century writers such as Francis Godwin and Cyrano de Bergerac voyaged to the Moon to colonize it with European culture.

[126]Burnet, 118. Burnet explicitly referred to the mountains of the Moon in the text of his survey of the Earth's mountain ranges; p. 112.

would map the Earth to move from paper descriptions to the construction of three-dimensional models, which alone could be effectively naturalistic:

> Tis true, there are far more Mountains upon the Earth than what are here represented, for more could not conveniently be plac'd in this narrow Scheme; But the best and most effectual way of representing the body of the Earth as it is by Nature, would be, not in plain Tables, but by a rough Globe, expressing all the considerable inequalities that are upon the Earth.[128]

Burnet lauded the ideal of constructing "a true Epitome or true model of our Earth." Such a map must model the globe in both form and matter. In form, it would be a "rough globe of the largest dimensions," including both mountains and ocean beds in all their disorder. In matter also it would correspond to the features it depicted; its coastal beaches would be made of sand, and its mountains composed of their actual rock types. Anything less would fail to convey the true nature of the Earth:

> The smooth Globes that we use, do but nourish in us the conceit of the Earth's regularity, and though they may be convenient enough for Geographical purposes, they are not so proper for Natural Science; *nothing would be more useful*, in this respect, than a rough Globe of the largest dimensions, wherein the Chanel of the Sea should be really hollow, as it is in Nature, with all its unequal depths *according to the best soundings*, and the shores exprest both according to matter and form, little Rocks standing where there are Rocks, and Sands and Beaches in the places where they are found; And all the Islands planted in the Sea-chanel in a due form, and in their solid dimensions. Then upon the Land should stand all the ranges of Mountains, in the same order or disorder that Nature hath set them there; And the in-land Seas, and great Lakes, or rather the beds they lie in, should be duly represented; as also the vast desarts of Sand as they lie upon the Earth. And this being done with care and due Art, would be a true Epitome or true model of our Earth.[129]

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[127]The great discrepancy between what Burnet had *done* (the conventional map he had drawn) and what he *said* he had done (a two-dimensional natural portrait of the Earth from space) is perhaps far more obvious to a modern viewer than it was to him (especially if we take later geological maps as our point of comparison, for the development of which Burnet's Theory was inconsequential). It seems that the cartographic conventions may appear "realistic" enough to those not exposed to other ways of naturalistic depiction, and that Burnet seems to have regarded his maps as naturalistic, to some degree, like the lunar portraits made with the telescope. Whenever "map" is used in discussion of Burnet, only the lunar depictions and geographic maps of his day are implied. Contrast Desmarest's regional maps of Auvergne, where specific peaks were depicted individually; Kenneth L. Taylor, "Nicolas Desmarest and Geology in the Eighteenth Century," in *Toward a History of Geology*, ed. Cecil J. Schneer (Cambridge: MIT Press, 1969), 339–356.

[128]Burnet, 118.

[129]Burnet, 118; italics added.

Clearly, to construct such naturalistic models of the terraqueous globe would require extensive and coordinated observations, more than topographical cartographers and mineralogical travellers would be able to carry out for another two centuries (but of course, this did not prevent him from asking the reader to imagine that such fieldwork had already been accomplished and that the resulting representations provided support to his Theory). After the conventional cartographic map (which he produced) and the fully naturalistic portrait of the Earth from space (which he said he had produced), the call for a rough globe amounts to a third level of visual rhetoric, a verbal ideal rather than a realized depiction, a model of the Earth that would be fully naturalistic. Burnet sought the immediacy of a concrete, material model to impart his vision in a mythopoeic manner. Such a representation would be self-authenticating; his readers might imagine they were *experiencing* the roughness of the globe instead of merely giving mental assent to it. In other words, Burnet aimed for a mythopoeic mountainous globe immediately accessible to imaginative experience.[130]

[130]Mythopoesis often may be involved in symbolic and emblematic expressions, but it is different from them. Still less is the mythopoeic necessarily either allegorical, mystical, or magical. Simply put, mythopoesis is one opposite extreme to abstraction. Strictly speaking, mythopoesis refers to any imaginative attempt to express or engender an immediate intuitive experience of the concrete actuality of a particular nonabstracted thing. This definition is admittedly abstract and discursive in order to presume nothing regarding notions such as "primitive mentalities" or "pre-logical thinking," nor any philosophical theory of aesthetics, nor is its application restricted to mythological stories *per se*. In Burnet's case the mythopoeic quality climaxes with the attempt to convey to the imagination an immediate experience of the Earth as a broken and shattered object, without abstracting its roughness away, by the use of physical material rather than cartographical symbols. The emblematic has already been described as one example of ornamental naturalism; here I suggest the mythopoeic as another kind of ornamental use of a naturalistic image. The mythopoeic possesses an experiential dimension which lends persuasive authority to naturalistic pictures. For this reason the mythopoeic may be more amenable to evidential uses, and the emblematic more effective in didactic uses, though both are obviously ornamental.

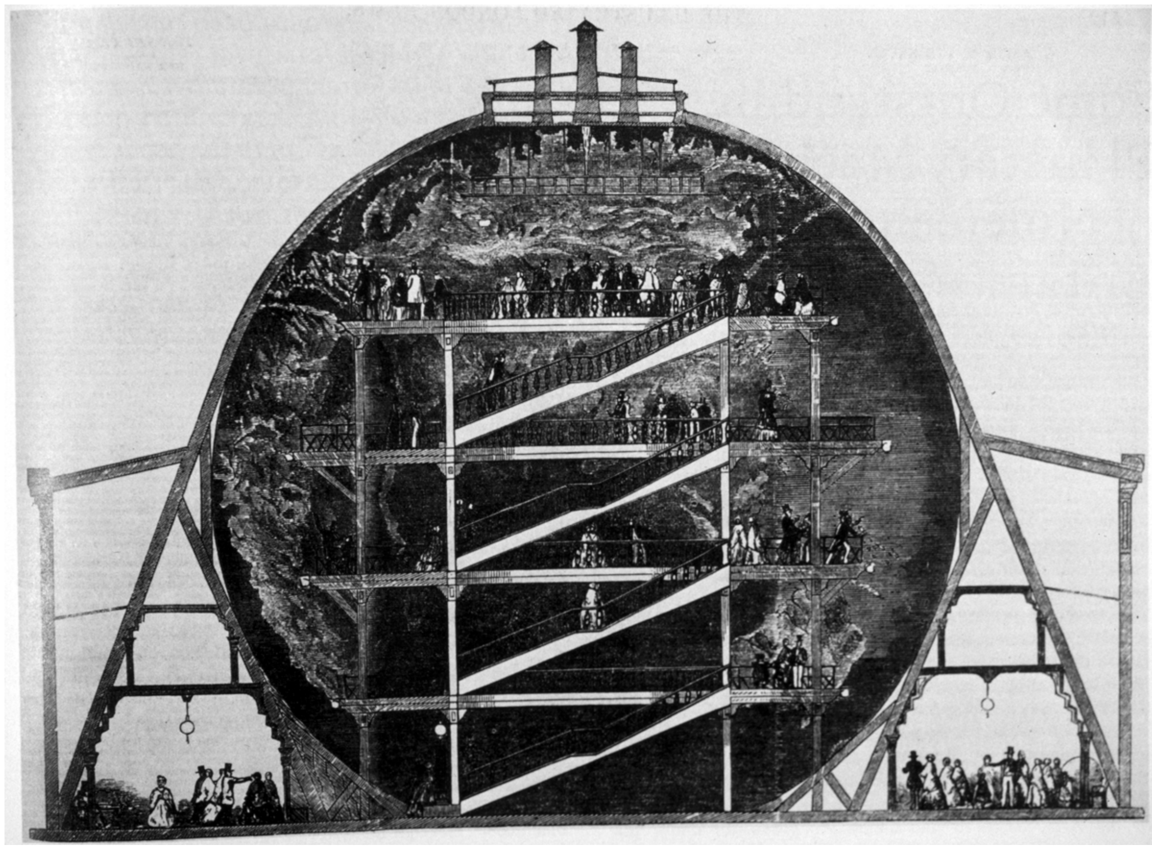

FIGURE 113. Wyld, Great Globe, 1851 Exhibition.

Description. "Mr. Wyld has made a grand discovery. He has satisfactorily proved that the interior of the globe is not filled with gases, according to Agassiz; or with fire, according to Burnet; neither has he filled it, like Fourier, with water. No, Mr. Wyld has now shown us that the interior of the globe is occupied by immense strata of staircases."[131]

Something like Burnet's ideal of a natural material map was implemented on a partial scale when White Watson (1760–1835) prepared geological sections with each stratum made of samples of the rocks themselves.[132] But James Wyld (1812-1887), owner of a cartographical firm in Charing Cross and honorary geographer to Queen Victoria and Prince Albert, con-

[131] *Punch*, cited by Hyde, p. 121. Ralph Hyde, "Mr. Wyld's Monster Globe," *History Today* 20 (1970): 118–123. My account of Wyld's globe follows Hyde; I have not seen Wyld's *Notes to Accompany Mr. Wyld's Model of the Earth* (Leicester Square, London, 1851).

[132] Trevor D. Ford, "White Watson (1760–1835) and his Geological Sections," *Proceedings of the Geologists' Association*, 1960, 71: 349–363.

structed a giant global view for the 1851 London Exhibition to mark the "commencement of a new era in geographical instruction." The structure did not include specimens of the actual rocks themselves (perhaps impossible on a global scale), but it was naturalistically colored: fertile areas were green, deserts yellow-ochre, snow caps on mountains were painted white, volcanos were topped with red craters and pieces of wool resembling smoke. An observation tower with four galleries made it possible to view any specific area closeup. A printed guidebook was made available, and lectures in descriptive geography were presented. Scaled sixty feet in diameter (3 inches per 10 miles) and for topographical relief (1 inch per 10 miles), Wyld's great globe remained a popular walk-through attraction for ten years.

§ 8. The Idiosyncrasy of Burnet

In his reliance upon Cartesian cosmogony, his appeals to apocalyptic interpretations of scripture, his respect for textual evidence in a predominantly textual mode of argument, and his arguments for a global deluge, Burnet may seem to later readers as paradigmatic for pre-geological thinking about the Earth. However, to his contemporaries Burnet was far from typical. The following brief survey of the ensuing controversy reveals his idiosyncrasy in claiming near certainty for a system in explicit opposition to the hexameral account.

§ 8-i. Bishop Croft's Scriptural Animadversions, 1685

In 1685, the year after the English translation of Burnet's first two books, Herbert Croft, Bishop of Hereford, railed that Burnet must be afflicted with lunacy, a "grave and sober madness."[133] Unimpressed with either Cartesian philosophy or classical antiquities, Croft was most alarmed by Burnet's reinterpretations of scripture: "I had not meddled with this mans Theory, unless he had given me great offence to see the Sacred Scriptures so abused, as to be made props to support such a rotten tottering building, as his Theory."[134]

Turning first to Burnet's crucial exposition of 2 Peter, Croft denied that it implied a difference between the antediluvian Earth and the present one.[135] According to Croft, Peter asserted a difference only for the form of judgment: one by water, the other by fire. Indeed, taken literally, Peter contradicted the Theorist.[136] However, the purpose of Peter was not to

[133]Herbert Croft, Bishop of Hereford, *Some Animadversions Upon a Book Intituled the Theory of the Earth* (London: Printed for Charles Harper, 1685). Hereafter "Croft, *Animadversions*."

[134]Croft, *Animadversions,* 1. Also Croft altogether rejected the *prisca sapientia* tradition constantly invoked by Burnet as a critical source of evidence for his Theory (discussed above, page 465 ff.).

[135]"Here is nothing mentioning any such diversity or opposition in the former Earth to the present Earth, no more than in the former Heavens to the present Heavens . . ." Croft, *Animadversions,* 11. Regarding Burnet's argument that the rainbow was instituted at the Flood, in support of a unique antediluvian water cycle, Croft countered that the rainbow could have been seen before the flood, just as a man may be washed before he is baptized. Croft, *Animadversions,* 31. Croft devoted his first 42 pages to dispatching Burnet's "principal Text."

teach philosophy,[137] and when referring to the "earth" he probably intended no more than the world of the ungodly.[138] Burnet remained free to try to demonstrate his "Petrine" theory, but he should not mistake biblical texts as evidence for it.

Unlike Burnet, Croft read Peter as glossing Moses rather than contradicting him. Most importantly, there was simply no way to reconcile Burnet's description of the smooth Paradisiacal globe with the gathering of the waters on the third day: "Is not this a rare Romantick way? and far exceeds all that ever hath been written of Sir Amadis de Gaule, or the Knight of the Burning Pestle."[139] In a lengthy discussion of the third day, after digressing to defend the traditional idea that the waters of the sea might be gathered in a heap above the level of the land, feeding cisterns in the mountains through subterranean passages, Croft wondered where on his Paradisiacal world Burnet would have put the whales.[140] For many believers, Burnet's scientific rehabilitation of the universal deluge was not worth the price of scotching the first chapter of Genesis. In this respect Croft was typical of many readers who could not square Burnet's Paradisiacal world with the textual account of the third day.

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[136]Croft, *Animadversions,* 33–34: "For St. Peter here in plain words affirms, that the Earth, before the Deluge, stood *part out of the water, and part in the water.* These are his plain words, without any such long Comment, as he hath brought upon them. But he objects, that this our English Translation doth not accord with the original Greek, which doth express it otherwise, saying, *The earth standing Out of the water and By the water, not In the water.* However these words of St. Peter express two distinct situations of the Earth, *Out of the water, and By the water....* But I shall show him from Gen. 1. (which these words have a relation to), that the words of St. Peter agree very well with the exposition of our English Translators, *Out of the water, and in the water*: for, Gen. 1.9, 10. it is said, God gathered the waters together unto one place and made the dry land appear." Compare the discussion of Burnet's use of the Vulgate in footnote 15 on page 441.

[137]Croft, *Animadversions,* 7: "'tis not a Philosophical Discourse to teach us the nature and constitution of the Heavens or the Earth; but to teach wicked men the nature of Sin, and to shew them the Judgment and Danger that constantly follows it: this is the business of this Epistle...."

[138]Croft, *Animadversions,* 22. Burnet pleaded for a literal interpretation, but the interpretation of "earth" was ambiguous. Croft's interpretation was literal, but there were others who applied it in a figurative sense to the Church. For example, the *New Testament* of the anti-millenialist Francis Fox included this annotation: "I do not understand these Expressions, new Heavens and a new Earth, in a literal Sense, as if the material Heavens were to be created anew; but in a figurative Sense, denoting that after the Destruction of Jerusalem and the Jewish Polity, there should be a new State of things; a new Church . . . ." Francis Fox, *The New Testament, With References set under the Text in Words at length: so that the parallel Texts may be seen at one View. To which are added, The Chronology, the Marginal Readings, and Notes chiefly on the difficult and mistaken Texts of Scripture. With Many more References than in any Edition of the English Bible,* 2 vols. (London: J. Wyat, 1722), 2: 993.

[139]Croft, *Animadversions,* 114.

[140]Croft, *Animadversions,* 153.

§ 8-ii. Diluvial Symmetry and Warren's Geologia, 1690

Croft's immediate and hostile response to Burnet should not surprise us. According to Genesis, in the beginning of the works of the six days God created the heavens and the Earth. To complete the first day, God separated the light from the darkness. On the second day, he separated the waters above the firmament from waters below. The events of these first two days offer a myriad of possibilities for the creative interpreter, but the most important for Theorists of the Earth was the separation event attributed to the third day—the "gathering of the waters":

> God said againe, Let the waters vnder the heauen be gathered into one place, & let the drye land appeare, and it was so. And God called the drye land, Earth, & he called ye gathering together of the waters, Seas: & God sawe that it was good.[141]

That the interpretation of the gathering of the waters could play an integral role in theorizing about the early Earth is manifest with the Theory of Thomas Burnet and its reception. For Burnet, the firmament was a hard shell which became the crust of the Earth. The waters gathered beneath it constituted a primordial subterranean abyss, closed to the sky. Croft was not alone in thinking that Burnet's hermeneutics had gone drastically wrong; as Erasmus Warren explained, Burnet's Theory "presents us with a new notion of the Firmament, and makes it to be quite another thing, than what it has always been said to be."[142] In *Geologia* (1690), the greatest part of which amounts to hexameral commentary, the Rector of Worlington maintained the traditional Protestant position that the firmament or expanse is the air in which the birds fly, and the waters above the firmament are the clouds (this was the view of the Geneva Bible and of Peter Martyr, for example; see the Appendix).[143]

[141] Genesis 1.9–10, Geneva Bible (1560). See the Appendix for the complete text of the hexameron.

[142] Erasmus Warren, *Geologia: or, a Discourse Concerning the Earth before the Deluge. Wherein the Form and Properties ascribed to it, in a Book intituled The Theory of the Earth, Are Excepted Against: And it is made appear, That the Dissolution of that Earth was not the Cause of the Universal Flood. Also A New Explication of that Flood is attempted,* History of Geology Series (facsimile reprints, Ayer Publishing; London: Printed for R. Chiswell, at the Rose and Crown in St. Paul's Church-Yard, 1690), 226. Hereafter, "Warren, *Geologia*."

To critique Burnet's errant interpretation of the third day, Warren appropriated Aristotle's arguments against Plato's Tartarus, conceding the existence of subterranean water but denying a central, closed watery abyss.[144] Aristotle's arguments against Plato were a standard point of discussion in hexameral commentaries, yet Warren's case ultimately rested on his hexameral exegesis, not on the classical texts or the arguments of Aristotle or Plato themselves. Like Croft, Warren rejected Burnet's interpretation of the work of the third day with hexameral commonplaces. A central watery abyss would be untenable, but not only for the reasons Aristotle adduced against Plato's central watery Tartarus. On the grounds of scriptural exegesis, given an abyss and firmament such as Burnet's theory supposed, Adam himself could not have exercised the dominion over the fish and whales which Genesis attributed to him, unless there had been open seas from the time of the creation.

Warren's *Geologia* had much more in common with the hexameral tradition than geology. Yet to confound Burnet's Cartesian-inspired claims of moral certainty, Warren put forward an alternative Theory of the Earth in two of the last three chapters in order to show that multiple interpretations of physical propositions in science were possible. Thus Warren, despite the conservative character of his idiom, became an unwitting participant in the Theory of the Earth tradition.

The gathering of the waters and associated interpretations of the firmament occupied much attention in Theories of the Earth. For those steeped in the hexameral tradition it was almost inconceivable that one could discuss the deluge without regard to the third day. Indeed, almost every hexameral commentator quite economically employed a single mecha-

[143]Considering why, on this view, the clouds do "not fall down and crush us to pieces, or bury us alive under Mountains of Ice," Warren was then led to discuss at length, as if transcribing a sermon, the providences of God revealed in the clouds. Warren, *Geologia*, 231.

[144]Warren allowed that a gathering of the waters is not inconsistent with the existence of subterranean water, since the ocean unites the Earth's waters comprising "one continued piece of Water, and so fills one continued space with its huge *moles*. I speak of a partial, and sometimes a secret continuity; for it is not always open, visible, and entire." That is, Warren supposed that the Caspian Sea is probably linked with the ocean via subterranean passages, given empirical evidence about rainfall, river flow, and fresh water upwellings as reported by ancient authorities. Warren, *Geologia*, 245.

nism for the gathering of the waters and the deluge. As we saw in Chapter 1, this "diluvial symmetry" amounted to either a parallel repetition or the same mechanism in reverse: either the gathering of the waters was replayed a second time to account for how the flood water drained off the face of the land, or the same natural process operating in reverse provided a source of the flood water, or both (for an interesting example which invokes Burnet's favorite passage from Peter see Table 22 on page 194). A theoretical symmetry between the work of the third day and the deluge is manifest not only in the commentators, but also in most of the Theories of the Earth which treated it, including the theories of Steno, Whiston, Woodward, Hooke, and Hutchinson, to name a few. In contrast to Burnet's nonreversible directionalism, diluvial symmetry was amenable to cyclic and dynamic as well as directional conceptions of the Earth, for to have a mechanism that could be called upon twice made it possible to imagine a third or more frequent repetition of similar events, consistent with the Stoic doctrine of repeated conflagrations, or perhaps on a smaller or regional scale in an overall directionalist framework (as with Steno).

§ 8-iii. Burnet's Broken Symmetry: Archaeologiae Philosophicae, 1692

Burnet's dis-integration of the creation and deluge represented a conspicuous exception to the usual diluvial symmetry, and this left his account decidedly less satisfying to readers (such as Croft or Warren) who were versed in the hexameral tradition. As early as the second chapter of the first book, Burnet excused his atypical emphasis upon the deluge and paradise at the expense of the works of the days:

> "And though we shall give a full account of the Origin of the Earth in this Treatise, yet that which we have propos'd particularly for the Title and Subject of it, is to give an account of the primaeval PARADISE, and of the universal Deluge: Those being the two most important things that are explain'd by the Theory we propose."[145]

Indeed, Burnet's emphasis lay chiefly upon the deluge, which he discussed before treating Paradise. Reversing the chronological order further downplayed the works of the days.

To seize the offensive, Burnet enumerated possible sources of water for the deluge, finding reason to reject the "Clouds above," the "Deeps below," and the "bowels of the Earth." Two other possible sources which he did not neglect, but considered far less viable, were the condensation of air and transmutation of Earth; explanations which had been respectively proposed by Augustine and Basil—the latter following Seneca. However, Burnet had the advantage of living after the voyages of discovery had made the supposition of a presently-existing watery hemisphere untenable. Expressing his penchant for the sphere as the most beautiful shape, Burnet opposed the hypothesis of standing waters (endorsed by Seneca, Luther, Calvin, and Croft), confessing: "a prodigious mass of water" sufficient to account for a universal deluge would appear "as a great Monster: It doth not look like the work of God or Nature."[146] The resulting riddle of how to find a source of water for the unique and universal deluge—a source of water once vast enough but now depleted—forms a core rhetorical query of Burnet's theory.

Because of Burnet's total disjunction of the mechanisms for the deluge and the third day, the deluge became a singular and unrepeatable event, in theory unlike the accounts given by Woodward, Hooke, or Whiston. A critic like Croft or Keill might object to its necessitarian inevitability, given its production by natural laws apart from any particular providence, but for Burnet the deluge constituted an absolutely unique event, a singular scene inevitably ordained by general providence in the historical drama of the Earth's past. Burnet's Earth history was directionalist, comprised of unique events, although those events unfolded inexorably via natural laws as ordained by God.

[145]Burnet, 27.
[146]Burnet, 28.

The break with Moses that Bishop Croft and Reverend Warren suspected was made official with publication of Burnet's *Archaeologiae Philosophicae* in 1692, two years after Warren's *Geologia* and the year Burnet became chaplain to William III.[147] In this work Burnet not only acknowledged that the hexameral account was irreconcilable with his Theory, but he argued that Moses wrote fables because of the vulgar capacities of the Jews. From this time on Burnet was branded an unbeliever. Croft had already suspected that Burnet had "very ill Principles, contrary to the Religion we profess... cloaked... under his Theory,"[148] but Burnet's notorious association with irreligion was just beginning. Because of the controversy over the *Archaeologiae Philosophicae*, Burnet was forced to resign his position as chaplain to the king.

§ 8-iv. Blount, Burnet, and the Oracles of Reason, 1695

With remarkable timing, Charles Blount's deistic manifesto *Oracles of Reason* (1695) appropriated two chapters of Burnet's *Archaeologiae Philosophicae*, translating them into English for greater distribution.[149] Despite his lengthy arguments against deism in the *Theory of the Earth,* despite the christology of his frontispiece and the prominent display of miracle in the preservation of Noah's Ark, Burnet was never thereafter able to dissipate accusations that he was a closet deist.

[147]Thomas Burnet, *Archaeologiae Philosophicae: sive Doctrina antiqua de rerum originibus* (London: Typis R.N., Impensis Gualt. Kettilby, 1692). An English translation appeared after his death: Thomas Burnet, *Doctrina Antiqua de Rerum Originibus: Or, An Inquiry into the Doctrine of the Philosophers of all Nations, Concerning the Original of the World*, Made English from the Latin Original by Mr. Mead and Mr. Foxton (London: Printed for E. Curll, at Pope's Head, in Rose-Street, Covent-Garden, 1736).

[148]Croft, *Animadversions*, "Preface."

[149]Blount, Charles. *The Oracles of Reason: Consisting of 1. A Vindication of Dr. Burnet's Archilogiae. 2. The Seventh and Eighth Chapters of the same. 3. Of Moses's Description of the Original state of Man, &c. 4. Dr. Burnet's Appendix of the Brachmin's Religion. 5. An Account of the Deist's Religion. 6. Of the Immortality of the Soul. 7. Concerning the Arrians, Trinitarians and Councils. 8. That Felicity consists in Pleasure. 9. Of Fate and Fortune. 10. Of the Original of the Jews. 11. The Lawfulness of Marrying Two Sisters Successively. 12. A Political Account of the Subversion of Jewdaism, and Original of the Millenium. 13. Of the Auguries of the Antients. 14. Natural Religion as oppos'd to Divine Revelation. 15. That the Soul is Matter. 16. That the World is Eternal, &c. In several Letters to Mr. Hobbs and other Persons of Eminent Quality, and Learning* (London, 1695); hereafter "*Oracles of Reason.*"

One of the chapters translated by Blount consisted of Burnet's argument that "the Original of Things inanimate, and the Universe, as Moses describes it in the First Chapter of Genesis, seems no less contrary to the Theory of the Earth."[150] The implied conclusion was that Moses rather than science (i.e., the *Theory*) must be in error. Moses and Burnet agreed that the Earth began as a chaos, and that the inanimate world preceded the animate, but this apparent concord was trivial. More importantly, they disagreed because the hexameron is Earth-centered rather than Sun-centered, the Sun only being created on the fourth day:

> The Hexameron truly seems to suppose that this Chaos filled and possessed the whole Universe how great soever, together with all the Heavens and Regions of the Air, which way soever they were diffused; as also that the brightest and most resplendent Stars were composed of this chaotic Matter, neither that there were any before the Birth and Creation of this our Earth. Which is what the very Letter of the Hexameron seems to import, & absolutely contradictory to the Nature of Things, as well as to all Philosophical Reasons.[151]

This fact alone would prove that Genesis offered a vulgar rather than a philosophical account, but Burnet pointed to further contradictions. Hexameral interpretations allowed for the creation of the angels either at the beginning or before the creation week. Wouldn't they have needed a place to stay? Thus the universe predates the Earth. Wouldn't it have taken many ages for them to fall? Thus the universe must be far older than the 6,000 years of Earth history commonly supposed.[152] All this supported Burnet's contention that the work of the third day was related "purely according to the Capacity of the Vulgar," and to refute the third day Burnet simply referred the reader to *The Theory.*[153]

[150] *Oracles of Reason,* 52.

[151] *Oracles of Reason,* 54.

[152] *Oracles of Reason,* 54–61.

[153] *Oracles of Reason,* 64. DESCRIBE ACCOMMODATION; NOTE NEITHER NEW NOR LIMITED TO PROTESTANTS.

§ 8-v. St. Clair Confutes the Abyssinian Philosophy, 1697

Given the choice between Moses and Burnet, Robert St. Clair did not hesitate to side with Moses.[154] Discussing Burnet's derivation of oil from the geogonic layers, St. Clair mused that "a good Woman that makes butter'd Cakes to sell them again, does more service to the Publick, than the Doctor has done by his Theory." Although he commended Warren's rebuttal, St. Clair set out to defended Genesis 1 on the basis of observation and experiment rather than just hexameral tradition. Believing that mountains and subterranean cavities dated from the creation, St. Clair first deployed the arguments of Bernardino Ramazzini against Burnet, and then proposed his own experimental model for an alternative cause of the deluge which would not contradict Genesis.

The bulk of St. Clair's book is his translation of the entire work of Ramazzini which included lengthy excerpts from Patrizi showing that Burnet's theory of a crustal collapse causing the deluge was held long before him by an Abyssinian philosopher.[155] Moreover, Ramazzini argued against Burnet's view of the deluge caused by the collapse of the crust into an underlying abyss of water.[156] Ramazzini held instead that Italy was once under the Adri-

[154]Robert St. Clair, *Abyssinian Philosophy Confuted: or, Telluris Theoria neither Sacred, nor agreeable to Reason, Being, for the most part, a Translation of Petrus Ramazzini, Of the Wonderful Springs of Modena. Illustrated with many Curious Remarks and Experiments by the Author and Translator. To which is added, A New Hypothesis deduced from Scripture, and the Observation of Nature. With an Addition of some Miscellany Experiments* (London: Printed for the author, and sold by W. Newton, 1697). Hereafter "St. Clair."

[155]Bernardino Ramazzini, *De Fontium Mutinensium admiranda scaturigine Tractatus Physico-Hydro-staticus* (Modena: Typis Haeredum Suliani Impressorum Ducalium, 1691). See "Platonic Theories of the Earth," beginning on page 175. Burnet also included excerpts from Patrizi in his *Archaeologicae Philosophicae*. A defender of Burnet noted: "But since the first writing of the Theory, there have been Aethiopick Antiquities produc'd from an Abyssine Philosopher, and transmitted to us by Francisco Patricio in his Dialogues. If that account he gives of the Aethiopian *Archaeologiae* be true and genuine, they exceed all other upon this subject. For they do not only mention this particular of the unity of seasons in the Primitive Earth, but the other principal parts of the Theory: As the Concussion and Fraction of the Earth, that the face of it before was smooth and uniform, and upon that disruption it came into another form, with Mountains, Rocks, Sea and Islands. These and other such characters are mentioned there, whereof the Examiner may see an account, if he please, in the last edition of the *English Theory.* The story indeed is surprising which way soever you take it, whether it was the invention of that Abyssine Philosopher, or a real Tradition deriv'd from the Aethiopian Gymnosophists." Thomas Beverley, *Reflections upon the Theory of the Earth, Occasion'd by a Late Examination of It. In a Letter to a Friend* (London: W. Kettilby, 1699), 24–25.

[156]Quoted above, page 184.

atic, and consists of the detritus of mountains washed down by ordinary rains in the process of time: "this growing up of the Ground so well distinguish'd, and so remarkable in the digging of all Wells, ought to be thought rather the Product of so many Ages, than the tumultuary and confus'd Work of the common Deluge."[157] Ramazzini argued that this conversion of sea into land must be the work of historical, postdiluvian ages, citing historical evidence to prove the retreat of the sea from ancient ports and towns.

If large portions of Italy were converted from sea to land in historical times, Ramazzini conjectured that the subterranean circulation ran between the mountains and the sea, not directly under Modena. Cautioning that he was conjecturing what was possible, not what was demonstrated, Ramazzini suggested that through subterranean passages the Adriatic had a secret commerce with storehouses of water in the Appennines, to which it was adjacent in the beginning of the world.[158] Thus a cistern in the mountains is more likely as a source of pressurized waters for the springs of Modena than an enclosed subterranean vault like Burnet's (see *Figure II* at the top of Figure 114). In chapter 7 Ramazzini described how he devised various experimental models of the springs of Modena, using buckets of water as the mountain cisterns (cf. *Figure 5* in the middle of the right column of Figure 114).[159]

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[157]Ramazzini, in St. Clair, 116. Ramazzini attributed his view to Scaliger, who advanced it against Van Helmont, 102–104.

[158]Ramazzini, in St. Clair, 123. See "Kircher's Encyclopedia of the Earth," beginning on page 527.

[159]Ramazzini, in St. Clair, 172ff: "Seeing then, according to our Hypothesis, the Waters of this hidden Source are movable and running, and withal ascend on high; because, as was said before, the Passage by which they go out, and fall into a Gulph, is strained; and seeing the Ascent into these Wells is constant and perpetual, nor can be done without some proportion to the height of their Cistern; because this Cistern is supposed by us to be in the Foot of the nearest Apennine Mountains, and higher by far than the Elevation of these Waters from the bottom of the Wells to the top; therefore I thought it would not be unprofitable nor unpleasant, if I endeavoured to shadow out, if not exactly to describe, such a Proportion. Suppose then there be a Vessel ABC full of water, to which a Pipe DE is fastened in a Horizontal Line, and whose Orifice is half shut, so that the water does not flow with a full Stream: Let there be likewise in the middle of the Pipe DF another glass Pipe HI inserted perpendicularly; therefore granting a free Passage to the water, I say, that the water will be lifted in the middle Pipe HI to such a height, that if the height of the water contain'd in the Vessel be of eight parts, the elevation of the water in the streight Pipe HI shall be of six parts; and such a Proportion will answer to any Division of the Mouth of the Pipe DF.... This was my Reasoning before I try'd whether the thing agreed to it; which I did, by inserting a wooden and square Pipe into the side of the Vessel, as in Fig. 3. and fitting a glass Pipe divided into 8 parts, and erected perpendicularly to the same Pipe; then putting a stop to the Pipe, which might only obstruct the half of it, I let the water run out, and observed that the water did rise in the glass Pipe in the same proportion, to wit, as 6 to 8."

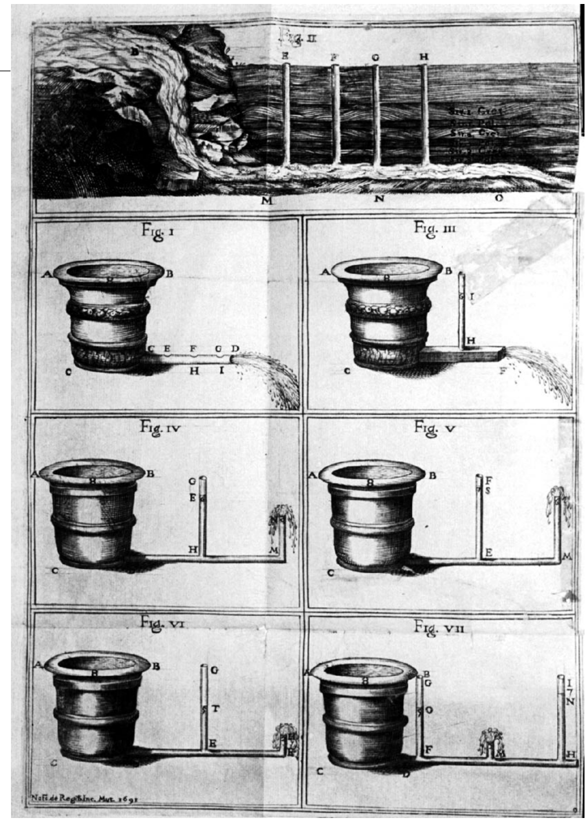

FIGURE 114. Ramazzini. Mountain cisterns as the source of the springs of Modena, with models.

Critics of Burnet were particularly fond of the alchemical and Kircherian belief that mountains contained cisterns of water from which the deluge may have come. For example, Warren defended such an account in the last two chapters of the *Geologia*. Burnet's Theory was irreconcilable with a cistern-based water cycle, which also implied the existence of mountains before the deluge. Accepting Ramazzini's arguments against Burnet's subterranean abyss, St. Clair proposed a new theory "more agreeable to Scripture and Observation." Like Ramazzini (and Warren and many other hexameral commentators, for that matter), St. Clair conceded that his own conjecture might not be true. However, with the example of Ramazzini before him, St. Clair insisted that his hypothesis was better than Burnet's because "it can be represented to the Eye how the thing is possible, which I am sure the Theorist cannot say of his." The image he presented to the reader's eye was an experimental model, although a chemical model to explain the deluge rather than a hydraulic simulation of the springs of Modena (Figure 115).

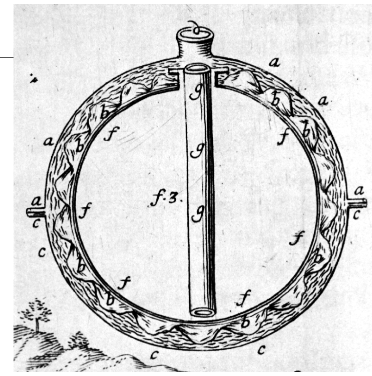

FIGURE 115. St. Clair, experimental model of the deluge.

To "satisfie some Gentlemen (who at that time did pass a course of Chymistry, with me about the Cause of an Effervescence, between an Acid and Alcaly," St. Clair created an apparatus as shown: "I had a Glass Pipe, such as they make the Baroscopes of, blown into the shape of a round ball at the end, that was Hermetically seal'd."[160] The glass pipe running through the axis of the globe serves as a model of Tartarus in the tradition of Kircher.[161] Mountains and subterranean cavities dating from the creation were represented by steel filings within the circumference of the globe. St. Clair then diluted Oil of Vitriol (sulfuric acid) with water and poured it upon the steel filings, producing a great effervescence from the container.[162] This effervesence suggested a chemical agency for causing subterranean waters to gush out in huge fountains upon the Earth:

> keep the Ball inclining, so that the steams arising may not get out at the hole, but being pented in may drive out the Water at the Pipe, which if the Ball were the Center of the Earth, would overflow all the surface of the Glass, and cover the Mountains of it, but this being wanted, we may imagine another glass ccc divided in two as you see, so that they may be cemented together when the other glass ball

[160] St. Clair, "That which gave rise to my conjecture, was an Experiment that I had occasion to make, to satisfie some Gentlemen (who at that time did pass a course of Chymistry, with me [no close parenthesis, sic] about the Cause of an Effervescence, between an Acid and Alcaly, which I hold to proceed from the sudden exclusion of Air, out of the Pores of the Liquors, and the Salts by the two contraries uniting closely into one Body: in order to which, I made out that there was an Air in all Liquors, by the boiling of Spirit of Wine, &c. in the Air-Pump, when the Air is exhausted: and this in opposition to Mr. Lemery, who only attributes it to a great commotion, and to Descartes, who attributes it to his Aether... to which I answer'd, that it could not be from the Aether, seeing I had it Prisoner in a Glass, and found it to contract it self with cold, and expand it self with heat... the Experiment was this, I had a Glass Pipe, such as they make the Baroscopes of, blown into the shape of a round ball at the end, that was Hermetically seal'd."

[161] See "Platonic Theories of the Earth," beginning on page 175. Note that neither Kircher nor St. Clair fit the primary conceptual criterion of crustal collapse for a Platonic Theorist, but they appropriated secondary Platonic themes nonetheless.

[162] "One might represent the whole of this to the Eye thus, let there be a round Ball to represent the Earth, (with a hole at the end, standing for the North Pole, at a, which Kircher supposes the Ocean to circulate thro' the Earth) of glass fff, full of risings to represent the Mountains bbb, let the Ball be fill'd with Water, and at the hole insert a Pipe ggg, which cement to the Neck, throw in by this Pipe some filings of Steel, after which some Oil of Vitriol...."

> is inclos'd, all the Water that runs out at the mouth of ggg, will over-flow the Hills bbb, &c.[163]

Many of St. Clair's contemporaries, both natural philosophers[164] and hexameral commentators,[165] applied their understanding of similar chemical processes to the Earth, but St. Clair modestly concluded with a jab at Burnet's excessive reliance upon ancient texts at the expense of observations and experiments:

> This is the substance of what I have to say of my Hypothesis, which if furnish'd with a good Library, with large Indexes, it were easie to make swell into a Volume big enough to deserve the title of a Theory; among which I might perhaps find, even in the Relicts of the Fiddler Orpheus himself, so much esteemed by our Theorist, or at least among the other Placita Philosophorum, enough to favor it.

[163]Citations are not given for quotations of St. Clair, because St. Clair's additions to Ramazzini are not numbered.

[164]For example, Isaac Newton conjectured in the famous Query 31 of his *Opticks* that a similar reaction caused earthquakes: "So when a Drachm of the above-mention'd compound Spirit of Nitre was poured upon half a Drachm of Oil of Carraway Seeds *in vacuo*, the Mixture immediately made a flash like Gun-powder, and burst the exhausted Receiver, which was a Glass six Inches wide, and eight Inches deep. And even the gross Body of Sulphur powder'd, and with an equal weight of Iron Filings and a little Water made into Paste, acts upon the Iron, and in five or six hours grows too hot to be touch'd, and emits a Flame. And by these Experiments compared with the great quantity of Sulphur with which the Earth abounds, and the warmth of the interior Parts of the Earth, and hot Springs, and burning Mountains, and with Damps, mineral Coruscations, Earthquakes, hot suffocating Exhalations, Hurricanes, and Spouts; we may learn that sulphureous Steams abound in the bowels of the Earth and ferment with Minerals, and sometimes take fire with a sudden Coruscation and Explosion; and if pent up in subterraneous Caverns, burst the Caverns with a great shaking of the Earth, as in springing of a Mine." Isaac Newton, *Opticks, or, A Treatise of the Reflections, Refractions, Inflections & Colours of Light,* based on the fourth edition, London, 1730, with a Foreward by Albert Einstein, an Introduction by Sir Edmund Whittaker, a Preface by I. Bernard Cohen, and an Analytical Table of Contents prepared by Duane H. D. Roller (New York: Dover, 1952), 379.

[165]Newton's explanation (footnote 164) was adopted by Bishop Patrick Symon in his commentary on Genesis to account for the gathering of the waters on the third day: "There being such large portions of Matter drawn out of the CHAOS, as made the Body of Fire and Air before-mentioned, there remained in a great Body, only Water and Earth; but they so jumbled together, that they could not be distinguished. It was the Work therefore of the third Day, to make a separation between them; by compacting together all the Particles which make the Earth, which before was Mud and Dirt; and then, by raising it above the Waters which covered its Superficies (as the Psalmist also describes this Work, Psalm CIV.6.) and, lastly, by making such Caverns in it, as were sufficient to receive the Waters into them. Now this we may conceive to have been done by such Particles of Fire as were left in the Bowels of the Earth: Whereby such Nitro-sulphureous Vapours were kindled, as made an Earthquake; which both lifted up the Earth, and also made Receptacles for the Waters to run into; as the Psalmist (otherwise I should not venture to mention this) seems in the fore-mentioned place to illustrate it, Psalm CIV. 7. where he says, *At thy rebuke they* (i.e., the Waters) *fled; at the voice of thy thunder they hasted away.* And so God himself speaks, Job XXXVIII.10 *I brake up for it* (i.e., for the Sea) *my decreed place, and set bars, and doors.* Histories also tell us, of Mountains that have been, in several Ages, lifted up by Earthquakes; nay, Islands in the midst of the Sea: Which confirms this Conjecture, That possibly the Waters were, at the first, separated by this means; and so separated, that they should not return to cover the Earth." Patrick Symon, Bishop of Ely, *A Commentary Upon the First Book of Moses, called Genesis* (London: Richard Chitwell, 1695),14–15.

§ 8-vi. Nicholls, Conference with a Theist, 1698

Bishop of Ely Symon Patrick published his popular commentary on Genesis (1695) with the aim of countering the deistic argument, based upon Burnet, that modern knowledge of the *Theory of the Earth* disproved the hexameral account:

> There have been those who have taken the liberty to say, That it is impossible to give any tolerable Account of the Creation of the World, in Six Days; of the Situation of Paradise; the Fall of our first Parents, by the seduction of a Serpent, &c. But, I hope, I have made it appear, there is no ground for such presumptuous Words: But very good reason to believe every thing that Moses hath related; without forsaking the literal Sence, and betaking our selves to, I do not know what, Allegorical Interpretations.... I hope, I have said enough to evince that it is not so incredible, as some have pretended.[166]

To refute the deists it was only necessary to conjecture a possible mechanism for the hexameron consistent with Genesis.

William Nicholls also published his *Conference with a Theist* (1698) to refute the deist challenge to the book of Genesis presented by Charles Blount's appropriation of Burnet. The first part of Nicholls' work argues against the eternity of the world; the second part attempts to remove "The Difficulties in the Mosaick Creation," and the third and last part defends the doctrine of the Fall.[167] Nicholls wrote in a dialogue format where objections to the faith were taken mostly from "a Book lately published, called *Oracles of Reason,* the first book I ever saw which did openly avow infidelity." Significantly, Nicholls noted that Burnet's *Archaeologiae Philosophicae* "makes up the far greatest part of the Book."[168] The two interlocuters in the

[166]Patrick Symon, Bishop of Ely, *A Commentary Upon the First Book of Moses, called Genesis* (London: Richard Chitwell, 1695), "Preface." See footnote 165 on page 508.

[167]Nicholls, William, *A Conference with a Theist. Containing an Answer to All the most Usual Objections of the Infidels Against the Christian Religion, In four parts,* 2d ed. (London: Printed by T. W. for Francis Saunders; and Thomas Bennet, 1698). Hereafter, "Nicholls." The second part, "Of the Mosaick Account of the Creation," is found on pages 95-191. In an essay appended to the work, dated 1697, Nicholls wrote "Shewing The Defects of Natural Religion; The Necessity of Divine Inspiration; The Rationale of the Mosaical Laws, and defence of His Miracles: Together, With an Account of the Deluge, the Origin of Sacrifices, and the Reasonableness of Christ's Mediatorship."

[168]Nicholls, "Preface."

dialogue are Philologus (who speaks for Burnet and deism) and Credentius (who speaks for Nicholls and Christianity). "Philologus comes one Afternoon to pay a Visit to Credentius, whom he finds in his study among a very large and choice Collection of Books in most Arts and Sciences; which he had procured for himself with no inconsiderable charge."[169] Philologus discovered Credentius transcribing something from Chrysostom, so Philologus seized the opportunity to take Chrysostom to task for believing in miracles and revelation. Credentius rose to the defense, and the conversation began.

When it came to the creation account, Philologus objected that according to Moses the universe was made at the same time as the Earth, and the stars were created for the sake of the Earth (these objections were in fact raised by Burnet).[170] Yet on the contrary, Credentius responded that Moses did not intend the hexameral account to encompass any region beyond the Sun and planets.[171] To this Philologus objected that according to Genesis 1 light is made before the Sun, as if God worked half the week in the dark. Credentius responded that the light might have been a lucid cloud which later became the Sun, and said that he could "better explain to you by this Scheme, which I desire your favour to look upon." The first image he produced was neither of the universe nor the Earth, but the initial chaos in a series of cosmogonic sections to show the origin of the solar system (Figure 116).

[169]Nicholls, 3.

[170]Credentius acknowledged: "I confess the generality of Divines, both Ancient and Modern, have thought the whole Universe was created in the Hexaemeron; because God is said to have then created the Heaven and the Earth, and because the Stars are mentioned in the fourth days work." Nicholls, 98.

[171]Genesis 1:16, "He also made the stars," was either a later interpolation, or the stars were mentioned with reference to seasonal rule (with the Moon) rather than as being created at that time. Credentius denied that God was chewing his cud before the creation of the Earth, and even conceded that a half dozen inhabited worlds may be imagined, if desired, around every fixed star. Nicholls, 100–104.

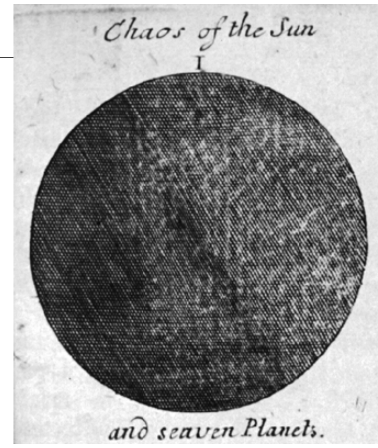

FIGURE 116. Nicholls, *Figure I,* "Chaos of the Sun and seaven Planets." A solar system cosmogonic section. LH.

> It is my opinion that upon the first formation, the whole space of the Magnus Orbis, which is all that space which is comprehended within the circle which Saturn describes about the Sun, was the Bounds of the Chaos. For the other Planets, Jupiter, Mars, &c. which are contained within this Circle, bear so many similitudes and relations one to the other and to our Earth, have the same common Luminary, the same Center, alike form and gravity, with many other Affections, which may be demonstrated of them, that to any reasonable Man they seem to be the production of one Creation. If the Sun was not created till your Creation, as Moses says positively it was not, we cannot imagine that all the other Planets, till that was created, went rowling all in the dark round an imaginary point, to no purpose. We must therefore assign them all one common time of Creation, which must be the Mosaical. The Chaos therefore must be of equal extent to the Creation, that is to take up all the Room within the aforesaid Circle. Now it seems most agreeable to Scripture, that this Chaotick matter was then first created out of nothing by God, Heb. 11.3. compared with 2 Mac. 7.28. That Original Creation therefore is represented in the Figure 1. Wherein is comprehended all the Matter in this solar World unformed and indigested, without Light or Motion.[172]

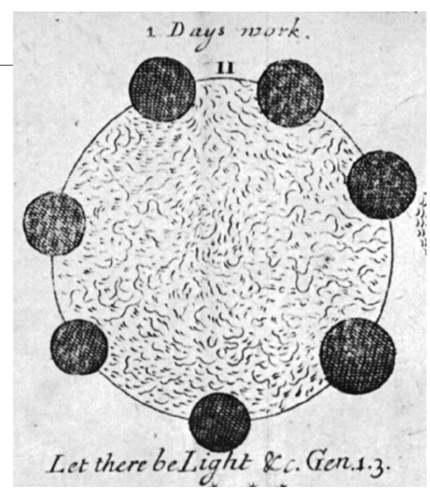

FIGURE 117. Nicholls, *Figure II,* "1. Days work. Let there be Light &c. Gen. 1.3" LH.

The opaque expanse of Figure 116 resembled a "Dark Muddy Globe" when the *fiat* for the creation of light was given on the first day. Then the Spirit of God incubated the abyss by putting it in motion, and the heavy parts retired to their centers and became the planets. This was the first day's work (Figure 117).[173]

[172]Nicholls, 109–111.
[173]Nicholls, 111–112.

Turning to the work of the second day, Philologus asked, "What are the waters above the firmament?"—feigning sympathy for poor Moses, who did not understand the water cycle and had to invoke a heavenly pond for rain. Credentius piously affirmed that if God says it, it must be true whether we understand it or not. But there may be a more intelligible interpretation, he continued: The firmament "is generally, and I think very well understood [as] the Atmosphere of the Earth, or the Regions of Air."[174] As we have seen, to identify the air with the firmament and by implication the clouds with the waters above the firmament was a conventional interpretation, at least outside scholastic circles. Yet Nicholls added a new twist in the context of his aim to account for the origin of the planets in the same way as the Earth. While he regarded the firmament as the Earth's atmosphere, the waters above the firmament he identified with oceans on the Moon.[175] The shading around each planet in Figure 118 reflects his suggestion that other planets likely have oceans and watery satellites as well:

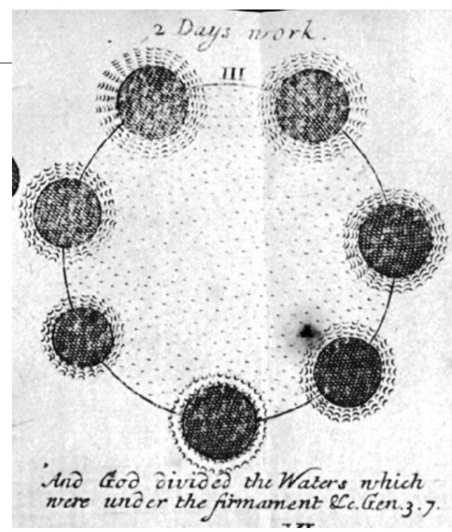

FIGURE 118. Nicholls, *Figure III,* LH.

Caption. "2 Days work. And God divided the Waters which were under the firmament &c. Gen. 3.7."

> "Now I suppose, that before the Work of the second Day, all this Planetary Water lay undistinguishably dispersed throughout the Expansum, and together with the Aether, made up that Pellucid Globe; which was left by the secession of the opake and terreous parts, that subsided to the seven respective Centres and formed the Bodies of the Planets. The work therefore of the second Day was, to make a Division of these Waters, to distribute them in proper proportions to the several Planets . . . ."[176]

[174]Nicholls, 114.

[175]Cf. footnote 340 on page 595.

[176]Nicholls, 115.

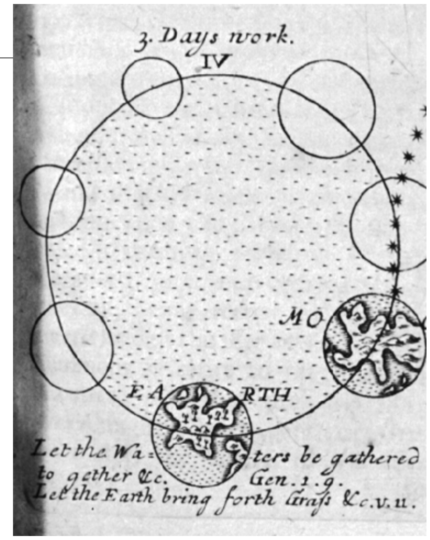

FIGURE 119. Nicholls, *Figure IV,* LH.

Caption. "3. Days work. Let the Waters be gathered to gether &c. Gen. 1.9. Let the Earth bring forth grass &c. v. 11."

Explanation. The Earth is shown at the bottom of the figure; the Moon above it to the right.

Thus stymied on the first two days, Philologus moved on to refute the third day's account, objecting that the channels of the seas could not have been hollowed out in one day's time; therefore the third day remained unintelligible. Credentius appealed to divine omnipotence: God is Almighty and therefore can hollow out the seas in one day by his power, just as he could do it in an instant if he so desired.[177] Thus Nicholls conceded that the ordinary operation of natural causes in the works of the days would require longer than six twenty-four hour periods, but he opined that they were accelerated as necessary to fit within the timespan. After the gathering of the waters, the Earth and Moon in Figure 119 are represented as global views.

Regarding the second half of the third day, Philologus made the spectacularly incisive objection, "Why are there no oranges in Greenland?"[178] To this Credentius distinguished between the immediate creation of plants, for which the Sun was not needed, and their natural production from seeds. Besides, if a natural cause were needed, adequate heat would have been available due to the contraction of the *expansum* on the previous days.[179]

[177]Nicholls, 118. "Why should God in his Creation be tied to the dull sluggish motion of his Creatures, since Motion is demonstrated to be infinitely fast or slow, as God pleases?" The previous invocation of divine omnipotence was for the second day.

[178]The logic of the objection is that if the Earth became covered with vegetation on the third day, before the creation of the Sun, then why do plants not grow where sunlight is absent now?

[179]Nicholls, 121.

Next Philologus caught Credentius in an apparent contradiction regarding the fourth day: If the planets were formed on the first day according to the scheme, how could they be made on the fourth according to Moses? Harking back to Augustine, Credentius answered that they grew to perfection by degrees throughout the six days. Their bulk was made at the beginning,

> yet they are said to be made the fourth day, because they are made the Moon and the Erratick Stars to us. They were before only Invisible Globes, but by the Light of the Sun, which was this day Created, they became Conspicuous and Reflected upon the Earth a bright shining Light, which they borrowed from thence.[180]

Moses did not mention their creation earlier because his intention was to give an account of the sublunary creation, not of each planet or of astronomy generally. His account is neither false nor philosophical, lest God be a liar or perplex and confuse the vulgar.[181]

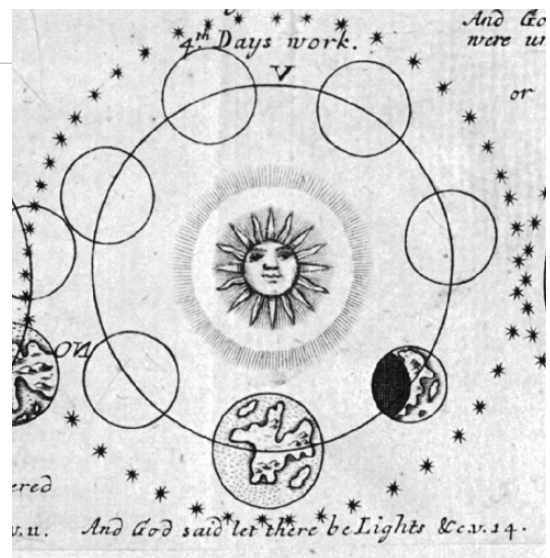

FIGURE 120. Nicholls, *Figure V,* "4th Days work. And God said let there be Lights &c. v. 14." LH.

Although not philosophically written, Moses' account could be understood, Nicholls suggested, if one supposed that unctuous matter, once diffused through the whole expanse, contracts to the center of the whole and on the fourth day breaks out into flame (Figure 120). The newly transparent aether is an appropriate medium for illumination, and the planets swim through it:

> The Planets therefore, and especially the Moon, are very properly said to be made this fourth day; because they made their first *appearance* upon this day to the

[180]Nicholls, 124.
[181]Nicholls, 126.

> Earth, they had then their first *use* put upon them of being Luminaries to this World.[182]

In Figure 120 the Moon is first subject to phases on the fourth day, and the stars become visible when they lie in a cone of night (compare *Figure VI* in Figure 121).

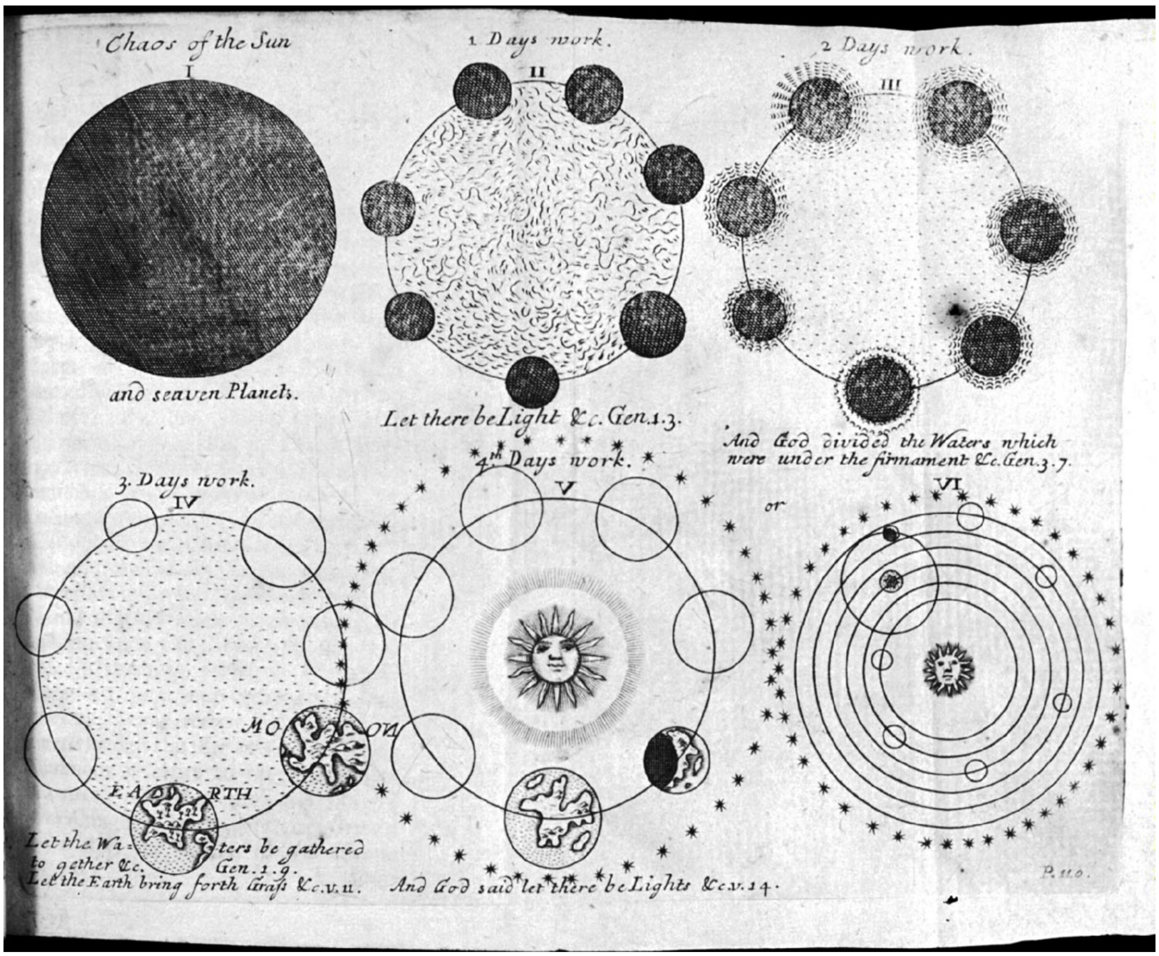

FIGURE 121. Nicholls, *Hexameral Plate*, figures I through VI

Philologus and Credentius discussed many more questions, such as whether the sixth day was long enough for all the narrated events to have taken place, whether it was risky to plan to propagate the species by beginning with just two people, and so on through the account of the

[182]Nicholls, 125–126.

Fall. Through it all Credentius maintained that "I should rather think, the Gentlemen of your way, instead of finding fault with Moses for a Plebeian Philosopher, should admire him for an excellent Vertuoso."[183] Yet if Moses was indeed a Virtuoso, Nicholls conceded that he was not always easy to understand. That this scheme was a possible way of understanding Moses intelligibly was all Nicholls meant to claim, disavowing any suggestion that his interpretation was certain:

> There is one thing in the last place which I would desire the Reader's Candor in, and that is my Explication of the Mosaick Creation of the Stars, a little out of the way of other Interpreters; which I would let him know, I do not deliver as my setled Opinion, by any Dogmatical Assertion, but only propound it Problematically, as a possible way of accounting for the relation of Moses, which destroys the Infidels charge of Impossibility; and which at last I leave to the Reader's Judgment, either to receive or to reject. And suppose this Hypothetical Scheme not to be exactly true, which I am not very eager to contend for; the cause of Religion will not suffer by it, nor the Infidels reap any advantage from it. This is only a Point of Philosophy and not Revelation; and if there be any Errour in it, I am to suffer for it and not Moses. If this Hypothesis be possible, it proves as much as is aimed at; for any way of shewing how Moses in his Account may be, is a good proof against those who assert it impossible to be.[184]

Croft, Warren, St. Clair, Patrick, Nicholls, and others emphasized the traditional Augustinian hermeneutical principles, seemingly ignored by Burnet, of proposing multiple and tentative explanations for scriptural passages pertaining to natural knowledge.[185] Burnet's extreme hermeneutical inflexibility was rejected with Anglican diffidence; the Burnet controversy made clear the dangers of too closely aligning biblical authority with science, raising a red flag for others who might continue to use scripture as a substantive resource or scientific encyclopedia. As skeptics from the days of Augustine to Burnet knew well, to affirm the legitimacy of multiple possible interpretations necessarily decreases confidence in any particular one. To avoid theological mistakes on the one hand and unwitting support of skeptics on the

[183]Nicholls, 121.

[184]Nicholls, Preface.

[185]Augustine. SEEMINGLY; actually Burnet knew them..... See Rappaport, 149.

other, it would be necessary to find more reliable auxiliary evidence rather than deriving theories from textual evidence prematurely. The hexameron remained one of the most important considerations for the corroboration, presentation, and reception of theories, but most actors recognized that a greater weight needed to be given to empirical evidence (as in the case of St. Clair and his chemistry) in the origination of schemes of Earth history. The hexameron was more wisely employed as a constraint for assessing theories developed by means of other evidence, with due acknowledgement of the plurality of physical interpretations it was exegetically possible to draw from it. Theoretical discussions about the Earth migrated out of the hexameral literature into the tradition of Theories of the Earth, as the length devoted to the hexameron markedly diminished in early eighteenth-century commentaries on Genesis. In Chapter 6, "Technical Naturalization: Portraits of a Dynamic Tradition," we will survey some of the global visions of eighteenth-century Theorists, some but not all of which continued to emphasize hexameral themes. But first, in the next section, we will review the variety of seventeenth-century hexameral idiom as it was expressed in global sections and views, casting our net more widely than just the controversy over Burnet.

§ 9. Contending Interpretations

In the previous section we have seen how the hexameral tradition collided with the Theory of the Earth of Thomas Burnet. If hexameral topics were so significant in shaping the reception of Burnet's Theory, then it will make sense in this section to enquire how hexameral idiom was expressed in global sections and views during the seventeenth century, beginning with two examples of biblical illustration selected to span the time period from the late sixteenth to the early eighteenth centuries.

§ 9-i. Hexameral Tradition and Global Illustrations

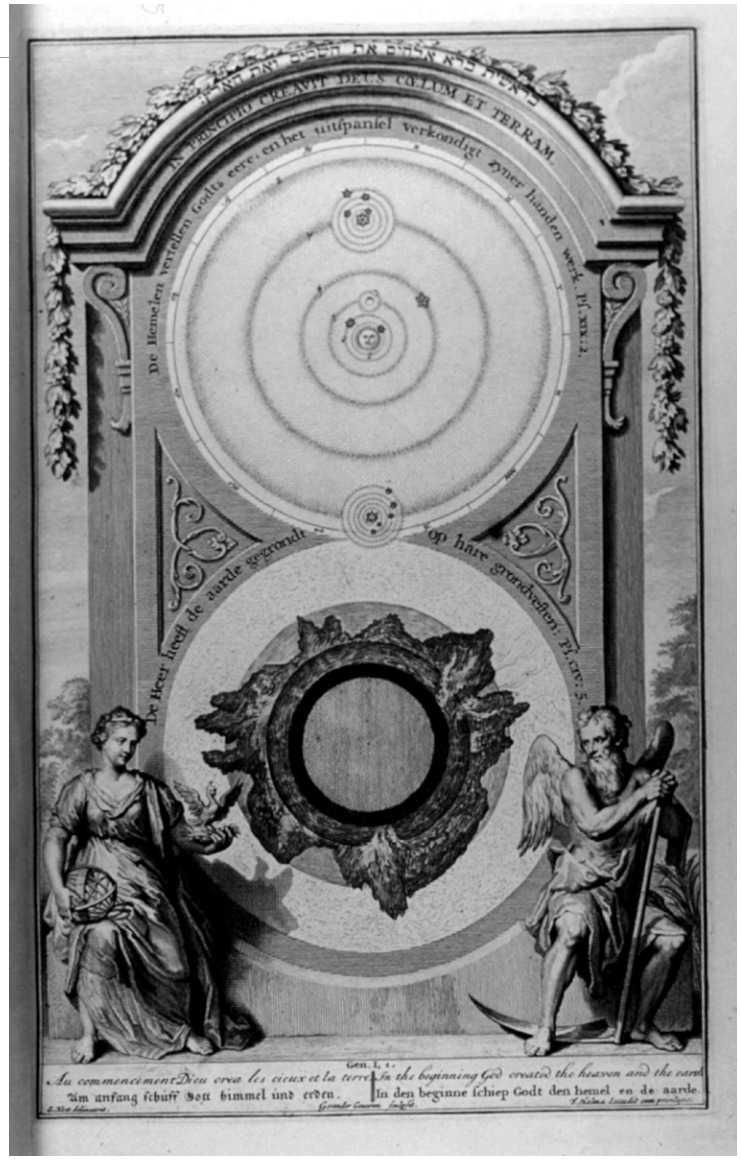

FIGURE 122. Gerard Hoet, hexameral illustration (1728). Courtesy University of Oklahoma, Bizzell Bible Collection.

Representations of the Earth often accompanied the first chapter of Genesis in illustrated Bibles. Consider twin cosmic and global sections published in 1728 drawn by Gerard Hoet to illustrate the creation of the "heavens and the earth" according to Genesis 1:1 (Figure 122).[186] This figure shows two equally-balanced orbs representing the creation of the heaven and the earth. The first chapter of Genesis underscored the significance of the Earth, leading commentators to regard consideration of

[186]Captions for Hoet's illustrations were given in German, English, French, and Dutch. Hebrew and Latin texts of the same verse are inscribed on a pediment near the top of the engraving. Included in Pierre de Hondt Haye, *Figures de la Bible* (N.p, 1728). This collection includes many illustrations by Hoet. University of Oklahoma, Bizzell Bible Collection, Case 23.4.

the Earth as an inquiry of equal stature to cosmology. Hoet depicted the heavens by a diagram of the Copernican system, where Jupiter has four satellites and Saturn five.[187]

Jacques Roger has argued that prior to Copernicus the Earth could only be conceived as a region of the cosmos rather than a body with a formative past; and Edward Grant has suggested that within scholastic discussions, the concept of a unified terraqueous globe was a late development, not occurring before the sixteenth century.[188] Without denying that cosmological considerations were critical to theories of the Earth before Copernicus (and after), or that the theory of a watery hemisphere was the predominant scholastic theory of the Earth, it is still the case that commentaries on Genesis emphasized the significance of the Earth relative to the heavens given the text's predominantly Earth-centered focus. The hexameral tradition included discourse about the integrity of the Earth, at times appropriating meteorological conceptions of a terraqueous globe. Like the meteorological tradition, but sometimes independently of it and on its own grounds, the hexameral tradition could emphasize the natural processes by which the Earth was formed and maintained.

Augustine provides an early and widely-known example, asserting on the basis of scriptural exegesis a broad and inclusive meaning for "Earth." For Augustine, the "Earth" was a body including not only elemental earth but also water and the lower region of the atmosphere.[189] The "Earth" was regarded not strictly as an element in a specific place, but as a functional body undergoing cycles of transformation, such as those involving the release of fiery exhalations into the atmosphere, necessary to sustain the existence of habitable dry land and ocean depths.[190]

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[187]The Dutch text of Psalm 19.2 adorns the view of the heavens: "De Hemelen vertellen Godts eere, en het uitspansel verkondigt zyner handen werke." In the KJV: "The heavens declare the glory of God: and the firmament sheweth his handiwork" (Psalm 19: 1).

[188]For Roger's arguments, see "Was Pre-Cartesian theorizing Essentially Cosmological?," beginning on page 225; for Grant's see "Shifting Centers in early Theories of the Earth," beginning on page 237.

In Hoet's global section, the Earth is made of four or five layers, with an outermost and presumably aerial sphere above the surface of land and water.[191] From beneath the terraqueous sphere fires rise upward within the mountains. Just outside the light central area is the darkest layer, perhaps an interior crust around the Earth's molten core.[192] The continents are the tops of mountains which emerge from the sphere of water; islands and submarine mountains also are shown. This illustration suggests that all the inequalities of the Earth's surface, from mountaintops to ocean depths, were formed at the same time and in the same way when the dry land appeared and the waters were gathered together to form the oceans on the third day.

Hoet's use of this global section to illustrate the creation week implies that mountains are part of the original creation, in some way as integral a part of the Earth as its oceans, and not

[189]"By analogy we call the whole spiritual and corporeal creation heaven and Earth. Hence, even this globe of tempestuous air is considered as belonging to the Earthly part of the universe; for, because of its misty vapors, it has the nature of body. But any peaceful region of air where winds and storm blasts cannot blow would belong to the celestial part of the universe." Augustine, *The Literal Meaning of Genesis*, trans. John Hammond, S. J. Taylor, 2 vols., Ancient Christian Writers, nos. 41–42 (New York: Newman Press, 1982), 1: 64. Cf. a parallel passage (1: 79): "The sacred writer, therefore, was not ignorant of the nature and order of the elements when he described the creation of visible things that move by nature throughout the universe in the midst of the elements, putting first the luminaries of the heavens, then the living creatures of the waters, and finally the living creatures of Earth. He did not pass over air; but whatever regions there are of pure tranquil air, where they say no birds can fly, are joined to the higher heavens and, being designated as heaven in Sacred Scripture, are understood as belonging to the loftier part of the universe. The term 'Earth,' therefore, is applied in general to all this lower region, including, in descent downwards, fire, hail, snow, ice, stormy winds, and all the deeps, until we come to the dry element that is called Earth in the strict sense."

[190]"The elements, then, as found both on the Earth and in the surrounding atmosphere are included under the term 'Earth' in the broader sense of that word. Thus, the familiar Psalm enumerates all the creatures above after beginning, Praise the Lord from the heavens; and then all the creatures below are called upon after the words, Praise the Lord from the Earth. Now under this second head are included stormy winds and all the deeps and the fire that burns when touched; and these are all grouped together under the term 'Earth,' because fire comes forth from Earth and water in motion and is itself in turn converted into the air. And although fire reveals its natural bent by the fact that it rises, it cannot reach the peaceful regions of the heavens above, because it is overpowered by the abundance of surrounding air, into which it is changed and thus extinguished." Augustine, *The Literal Meaning of Genesis*, trans. John Hammond, S. J. Taylor, 2 vols., Ancient Christian Writers, nos. 41–42 (New York: Newman Press, 1982), 1: 80. The allusion is to Psalm 148.7. Cf. Cicero, *De natura deorum*, II.9.

[191]Psalm 104.5 adorns the global section of the Earth: ""De Heer heest de aarde gegrondt op hare grondvesten." In the KJV: "Who laid the foundations of the Earth: that it should not be removed for ever" (Psalm 104: 5). That the Earth is not to be "moved" could be interpreted as applying not to its motion through space in the Copernican system, but rather to constant appearance of dry land above the sea. It is therefore not surprising that the next illustration, for the Garden of Eden, depicted mountains as part of the original paradise.

[192]Compare layer *M* on Descartes' geogonic plates, *e.g.* Figure 101 on page 476, which represents a crust of hardened sunspot material surrounding the remaining core of an extinguished star.

merely the result of Noah's deluge. In a classic study, Marjorie Hope Nicolson emphasized the aesthetic appeal in England, particularly among Cambridge Platonists like Burnet, of an originally smooth surface of the globe. Mountainous disorder, as they perceived it, reflected the awful ruin of a former Paradise.[193] However, such an aesthetic sensibility ran counter to traditional hexameral discourse, as Hoet's next illustration reveals (Figure 123). In the company

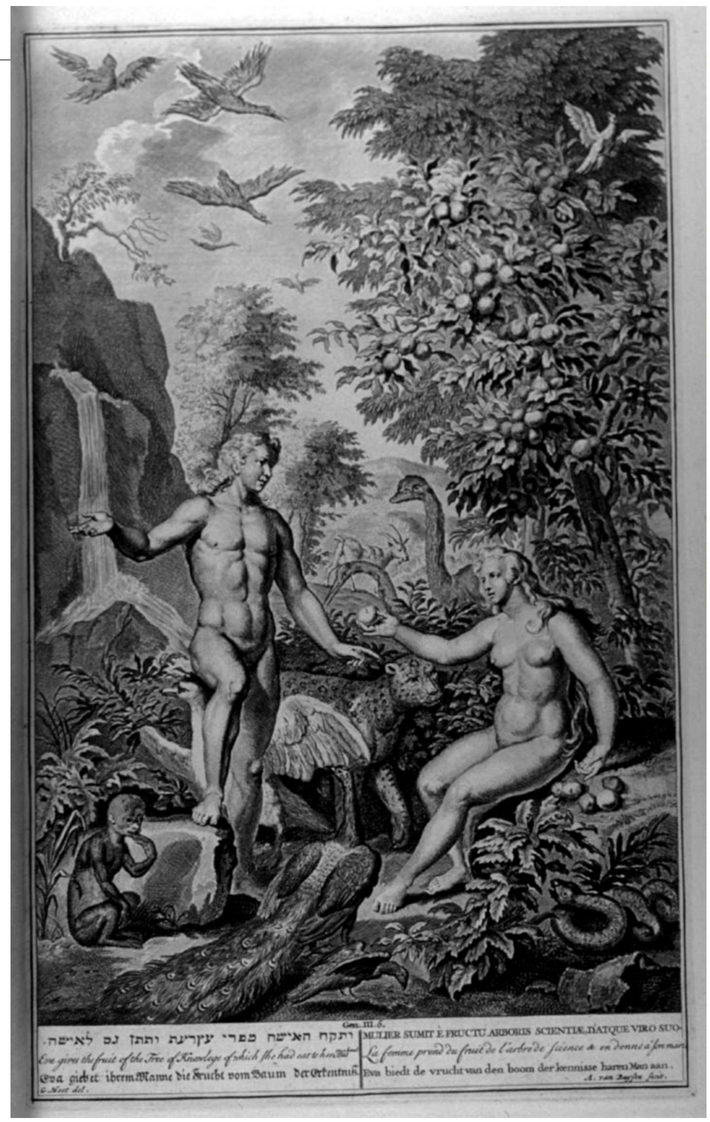

FIGURE 123. Gerard Hoet, mountainous Eden (1728). Courtesy University of Oklahoma, Bizzell Bible Collection.

of exotic animals, Adam and Eve consider their moral choices against the backdrop of tall mountains. Given Hoet's global section it could not have been otherwise: mountains were made at the same time as the ocean beds, then as now playing an essential role in the Earth's water cycle.

The character of the Garden of Eden was a commonplace problem often discussed in commentaries on Genesis. Although not strictly part of the hexameral account of Genesis 1, discussions of Eden inevitably mani-

[193]Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca: Cornell University Press, 1959).

fest commentators' implicit understandings of the state of the Earth at the conclusion of the six days. Far from being a novel interpretation of the Earth's topography, Hoet's representations maintain an utterly conventional hexameral practice, one reflected in the Geneva Bible. A woodcut entitled "The Sitvacion of the Garden of Eden" is found in both English and French editions of the Geneva Bible at the end of chapter two (Figure 124).[194] Eden is surrounded by mountainous country, from which luxuriant rivers flow. The Earth's inequalities, its water cycle and its precious stones, were present in its paradisiacal state.

FIGURE 124. Geneva Bible (1560), Eden (Genesis 2). Courtesy University of Oklahoma, Bizzell Bible Collection.

The purpose of the Geneva Bible's map of Eden was to depict the geographic location of Eden as exactly but obscurely described in Genesis 2:10-14:

> And out of Eden went a riuer to water the garden, and from thence it was deuided, and became into foure heades. The name of one is Pishon: the same compasseth the whole land of Hauilah, where is golde. And the golde of that land is good: there is also bdelium, and the onyx stone. And the name of the seconde riuer is Gihon: the same compasseth the whole land of Cush. The name also of ye third riuer is Hiddekel: this goeth towarde the Eastside of Asshur: and the fourth riuer is Perath.[195]

[194]See the Appendix for introductory comments about the Geneva Bible. In this map of Eden, place-names are given in French with English translations in the margin as follows: La Grand Armenie = Armenia the Great; Terre de Havila = Land of Hauilah; La cheute d'Euphrates = the fall of Euphrates; La cheute de Tigris = the fall of Tigris; Le Golfe de la mer Persique = The golfe of the Persian sea. These are described in verses 8-14 of Genesis 2.

This passage had long puzzled commentators, calling forth their best classical and geographical scholarship.[196] While mystical interpreters like Origen could allegorize it away, most ancient commentators discerned in this text a geographical description requiring a literal interpretation. Few doubted that the last two rivers were the Tigris and Euphrates, but the identities of the first two rivers were not easy to determine. Establishing what became a commonplace, Josephus, Jerome, Ambrose, and Augustine identified the Pishon with the Ganges and the Gihon with the Nile, corresponding to their identification of Havilah with India and Cush with Africa. Responding to the obvious geographical difficulties arising from designating four widely separated rivers as arising from a single source in Eden, Augustine reasoned that long subterranean channels (analogous to short channels presently known to link certain nearby rivers) must link the distant headwaters of the Nile and Ganges to the source of the Tigris and Euphrates.[197] Others accepted the entire drainage basins of these four rivers as the land of Eden, nearly coextensive with the entire surface of the dry land, prepared for Adam's descendants had they remained in an unfallen state.[198]

Martin Luther agreed that "We must think of a very wide area of land [as Eden], because this garden had been created to be the exclusive and perpetual dwelling place for Adam and all his descendants, of whom there would be a very great number."[199] But Luther was no Burnet; he denied that Moses meant for his readers "to imagine that Eden was the entire earth.... For the text expressly distinguishes the Garden of Eden from the rest of the earth."[200]

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[195]Marginal notes in the Geneva Bible, as well as the figure caption, identify the Hiddekel river as the Tigris and the Perath river as the Euphrates.

[196]Commenting on this text, Luther noted that "This is one of the greatest causes of offense in Moses." Martin Luther, *Lectures on Genesis, Chapters 1–5*, ed. Jaroslav Pelikan and Daniel E. Poellot, vol. 1 of *Luther's Works*, 50 vols. (St. Louis: Concordia Publishing House, 1958), 97.

[197]Augustine, *Literal Meaning of Genesis,* Book VIII, chapter 7.

[198]Incidentally, this interpretation compelled many commentators to argue that sexual relations between Adam and Eve were licit, and not the source of original sin.

[199]Luther, 97.

[200]Luther, 98.

Accepting the traditional identification of the Ganges and the Nile, Luther's solution was to invoke the deluge of Noah as an agent that obliterated the ancient topography of the Earth, so that the rivers now follow different courses than Moses described.[201]

In contrast to Luther, Jean Calvin denied that the text referred to either the Nile or the Ganges, and brought to a lengthy discussion the critical skills and reading habits of a humanist textual scholar.[202] Acknowledging the difficulties involved in rescuing Moses from unintelligibility, Calvin nevertheless rejected Luther's appeal to the effects of the deluge.[203] As Josephus had implied in the first century, Calvin believed that the deluge was tranquil in the sense that primeval topography was not obliterated in the flood.[204] Rather, Calvin inferred from the text that the "four heads" of the river could refer to mouths as well as to sources, and he found corroboration in classical texts such as Pliny and Strabo for his view that the Tigris and Euphrates rivers were once confluent in the area of Babylon. Thus two sources existed for one river which again divided to form two mouths. South of Babylonia the divided river flows by two separate mouths to the Persian Gulf. The stream on the Persian side (Havilah) is the Pishon and the stream on the Arabian side (Cush) is the Gihon. To convey this more

[201]"For the entire surface of the earth was changed.... Thus I believe that before the Flood the Mediterranean Sea was not surrounded by land, but that the channel in which it now has its place was produced for it by the Flood. Likewise, the area of the Red Sea without a doubt was formerly a fertile plain and, as is likely, some part of this garden. So also the remaining gulfs, the Persian, the Arabian, etc., consist of remnants of the Flood. Therefore one must not imagine that the source of these rivers is the same today as it was at that time;... after its corruption one must speak about all of nature as about a new face of things, which nature put on first because of sin, then because of the universal Flood." Luther, commentary on Genesis 2: 11-12, 98-99.

[202]John Calvin, *Genesis*, trans. and ed. John King (Edinburgh: Banner of Truth Trust, 1965), 118-124. Calvin cited Pliny, Pomponius Mela, Arrian, and Strabo, as well as scripture. On Calvin as a humanist scholar see William J. Bouwsma, *John Calvin: A Sixteenth-Century Portrait* (Oxford: Oxford University Press, 1988).

[203]"From this difficulty, some would free themselves by saying, that the surface of the globe may have been changed by the deluge; and, therefore, they imagine it might have happened that the courses of the rivers were disturbed and changed, and their springs transferred elsewhere; a solution which appears to me by no means to be accepted. For although I acknowledge that the earth, from the time that it was accursed, became reduced from its native beauty to a state of wretched defilement, and to a garb of mourning, and afterwards was further laid waste in *many places* by the deluge; still, I assert, *it was the same earth* which had been created in the beginning." 119. (Calvin did not cite Luther by name here, consistent with his characteristic, Augustinian charity toward different exegeses of obscure texts not involving central articles of faith.)

[204]Cf. Josephus, *Antiquities*, Book I, chapter 2, number 3. Josephus reported that an antediluvian pillar was still standing in his day, a fact which many early modern scholars took as evidence that the deluge was relatively tranquil and did not obliterate geographical topography. Calvin did not cite Josephus explicitly, but subsequent writers such as Warren cited both Josephus and Calvin on this point.

clearly he provided a map, in which mountains appear as an uncontroversial feature. This map of Eden, first printed in Calvin's *Commentary on Genesis,* was the same as that later used in versions of the Geneva Bible. This was the problem of cosmography for which the editors of the Geneva Bible appropriated both Calvin's woodcut and his interpretive solution (the latter was adopted in the marginal notes).[205]

Figure 125 and Figure 126 show two later examples of a seventeenth-century and an eighteenth-century scholar addressing the problem of the location of paradise, and the question proved significant for discussions of New World natural history and biodistribution.[206] In the next section we will examine a major figure who insisted that mountains date from the creation and were part of the original situation in the garden of Eden.

[205]Calvin's commentary on Genesis first appeared in Latin in 1554, predating the Geneva Bible by six years. The first English translation by Thomas Tymme was published in 1578. Both include the same illustration. The English-version caption for the map of Eden summarizes Calvin's interpretation: "Because mencion is made in the tenth verse of this seconde chapter of the riuer that watered the garden, we muste note that Euphrates and Tygris called in Ebrewe, Perath and Hiddekel, were called but one riuer where they ioyned together, els they had foure heades: that is, two at their springs, & two where they fel into the Persian sea. In this countrey and moste plentiful land Adam dwelt, and this was called Paradise: that is, a garden of pleasure, because of the frutefulnes and abundance thereof. And whereas it is said that Pishon compasseth the land of Hauilah, it is meant of Tygris, which in some place, as it passed by diuers places, was called by sundry names, as some time Diglitto, in other places Pasitygris, & of some Phasin or Pishon. Likewise Euphrates (which were but two riuers, and some time when they ioyned together, were called after one name) were according to diuers places called by these foure names, so that they might seme to haue bene foure diuers riuers."

[206]See Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven: Yale University Press, 1983).

TABLE 53. Mountains formed at the Creation

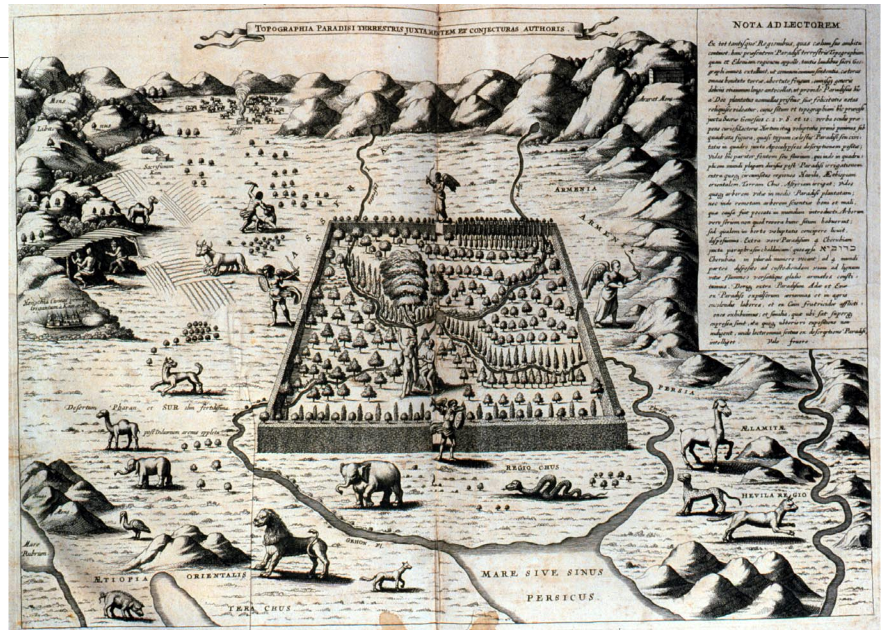

FIGURE 125. Kircher, *Arca Noë* 1675, Eden. LH.

FIGURE 126. Scheuchzer, *Physica Sacra* (1734), Location of the Eden. LH.

§ 9-ii. Kircher's Encyclopedia of the Earth

FIGURE 127. Kircher, *Subterraneus mundus* (1664), Frontispiece. LH.

The range of interests displayed by Athanasius Kircher (1602–1680) is staggering, even in a century renowned for universal scholarship.[207] Despite his failure to decipher Egyptian hieroglyphics, he was a master of a dozen European and Oriental languages. His forty-odd works include studies of ancient civilizations, China, mathematics, optics, magnetism, and medicine. Both highly praised and an object of ridicule, these works served many seventeenth-century scholars as a ready-reference library on virtually every scientific topic.[208] A Jesuit at the Collegio Romano, Kircher became curator of the university's museum which housed natural history objects sent to Rome from missionaries around the world.

[207]On Kircher's life and general career see Thomas Leinkauf, *Mundus combinatus: Studien zur Struktur der barocken Universalwissenschaft am Beispeil Athanasius Kirchers SJ (1602–1680)* (Berlin: Akademie Verlag, 1993); Jose A. Bach, "Athanasius Kircher and His Method: A Study in the Relations of the Arts and Sciences in the Seventeenth Century" (Ph.D. dissertation, University of Oklahoma, 1985); Martha R. Baldwin, "Athanasius Kircher and the magnetic philosophy" (Ph.D. dissertation, University of Chicago, 1987); Martha R. Baldwin, "Alchemy and the Society of Jesus in the Seventeenth Century: Strange Bedfellows?" *Ambix* 40 (1993): 41–64; Carlos Ziller Camenietzki, "L'Harmonie du Monde au XVIIe Siècle: Essai sur la Pensée Scientifique d'Athanasius Kircher" (Ph.D. Dissertation, Université de Paris IV-Sorbonne, 1995); Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994); and Thomas L. Hankins and Robert J. Silverman, *Instruments and the Imagination* (Princeton, N.J.: Princeton University Press, 1995).

[208]Some of the ridicule resulted from Kircher's uncomprehending criticism of Kepler; from his rejection of Copernicanism in favor of the Tychonic system accepted by the Jesuit order; from his polemical denunciations of spiritually- or theologically-minded alchemists such as Robert Fludd; and from his uncritical acceptance of anecdotal matters of fact and fanciful travellers' tales. On these matters see the references cited in footnote 207.

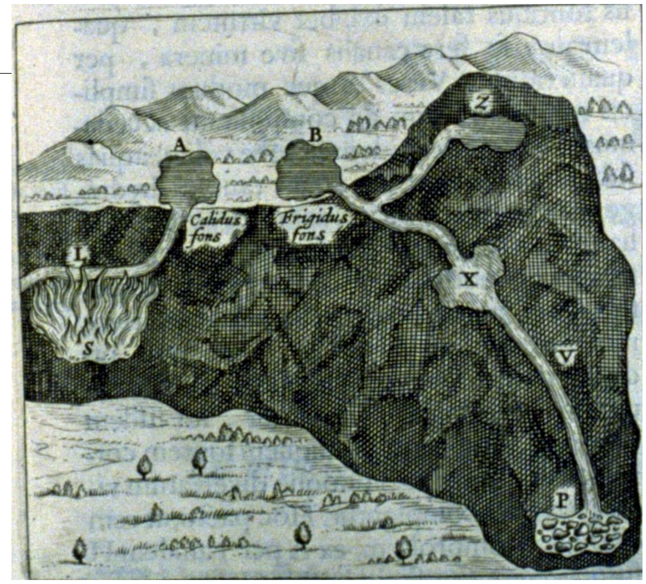

FIGURE 128. Athanasius Kircher, *Mundus subterraneus*, 1664, 257. HSCI.

Explanation. Hot (*Calidis fons*) and cool springs (*Frigidus fons*) in close proximity.

Three of Kircher's works developed his Theory of the Earth and were reprinted and frequently alluded to or quoted by later Theorists: *Itinerarivm Exstaticvm* (Rome, 1656)[209]; *Mundus Subterraneus* (Amsterdam, 1664–1665); and *Arca Noë* (Amsterdam, 1675).[210] Here we will focus on the visual illustrations of *Mundus subterraneus*, in which two richly-embellished global sections depicted the interlaced systems of air, fire, and water within the Earth.[211] Executed in an exuberant Baroque style, the dramatic sections manifest Kircher's global vision in a uniquely memorable way.[212] Yet the sections were not printed at the front of the two folio volumes, nor were they displayed in an unusually prominent position; rather, they are found in the midst of a miscellany of regional marvels known through a combination of classical

[209]A second edition is Athanasius Kircher, *Iter Extaticum Coeleste... Accessit ejusdem Auctoris Iter Exstaticum Terrestre, & Synopsis Mundi Subterranei* (Würzburg: Sumptibus Joh. Andr. & Wolffg. Jun. Endterorum haeredibus, prostat Norimbergae apud eosdem, 1660). Studies include Katharine Brownell Collier, *Cosmogonies of our Fathers: Some Theories of the Seventeenth and the Eighteenth Centuries* (New York: Columbia University Press, 1934; reprinted New York: Octagon Books, 1968), chapter 5; Carlos Ziller Camenietzki, "L'Extase Interplanétaire d'Athanasius Kircher: Philosophie, Cosmologie et Discipline dans la Compagnie de Jésus au XVIIe siècle," *Nuncius* 10 (1995): 3–32; and Barbara Bauer, "Copernicanische Astronomie und Cusanische Kosmologie in Athanasius Kirchers *Iter exstaticum*," *Pirckheimer-Jahrbuch: Im Auftrag des Vorstandes der Willibald Pirckheimer Gesellschaft* 5 (1989): 69–107.

[210]Athanasius Kircher, *Arca Noë, in Tres Libros Digesta, quorum I. De rebus quae ante Diluvium, II. De iis, quae ipso Diluvio ejusque duratione, III. De iis, quae post Diluvium à Noëmo gesta sunt, Quae omnia novâ Methodo, nec non Summa Argumentorum varietate, explicantur, & demonstrantur* (Amsterdam: Apud Joannem Janssonium à Waesberge, 1675). Studies include Don Cameron Allen, *The Legend of Noah* (Urbana: University of Illinois Press, 1949), appendix.

[211]Athanasius Kircher, *Mundus Subterraneus, in XII Libros digestus*, 2 vols. bound in 1 (Amsterdam: Apud Joannem Janssonium & Elizeum Weyerstraten, 1664–1665); there was a second edition in 1668 and an enlarged third edition in 1678. Studies of this work include Collier (footnote 209); Gerhard F. Strasser, "Science and Pseudoscience: Athanasius Kircher's *Mundus Subterraneus* and his *Scrutinium ... Pestis*," in *Knowledge, Science, and Literature in Early Modern Germany,* ed. Gerhild Scholz Williams and Stephan K. Schindler (Chapel Hill: University of North Carolina Press, 1996), 219–240;

reports, travel accounts, and Kircher's own observations during field expeditions to nearby sites in southern Italy. Numerous small-scale sketches throughout *Mundus subterraneus* illustrate particular surface features and geographical configurations of interest, such as the appearance of hot springs and cold springs in close proximity (Figure 128), or the accounts of the Andes received from missionaries in South America (Figure 136). Kircher's global sections are composites of these regional marvels. Both the regional sketches and the global sections suggest the kinds of underground structures one might suppose in order to explain the surface phenomena observed in particular places around the world.

Kircher emphasized investigations on a regional scale, suggesting that every aspect of the geocosm depicted in the sections was manifest in a single specific region of the Earth:

> Having a very earnest desire, a long time, to understand the Miracles of Subterraneous Nature . . . . I found such a Theater of Nature, displaying herself under wonderful variety of things, as I had with so many desires wished for. Sith what ever thing occurs, in the whole body of the Earth that is wonderfull, rare, unusual, and worthy of Admiration, I found contracted here, as it were, in an Epitomie, by a certain industry of wise and sagacious Nature.[213]

[212]The two global sections were combined with only slight modification to make a frontispiece accompanying a brief, popular selection of *Mundus Subterraneus* in English, published in London in 1669. In the English anthology a three-page "explication of the Schemes" appeared before the table of contents, making Kircher's explanation of the sections quickly accessible. *The Vulcano's: Or, Burning and Fire-vomiting Mountains, Famous in the World: With their Remarkables. Collected for the most part out of Kircher's Subterraneous World; And expos'd to more general view in English, upon the Relation of the late Wonderful and Prodigious Eruptions of Aetna. Thereby to occasion greater admirations of the Wonders of Nature (and of the God of Nature) in the mighty Element of Fire* (London: Printed by J. Darby, for John Allen; and are to be sold by him, at the White Horse in Wentworth Street near Bell Lane; And by Benjamin Billingsly at the Printing Press in Broad-Street near Gresham Colledg, 1669). Hereafter, Kircher, *Vulcano's*. As one example of the general accessibility of Kircher's views, the English version was cited by Cotton Mather, *The Christian Philosopher* (1721); Cotton Mather, *The Christian Philosopher*, ed. Winton U. Solberg (Urbana: University of Illinois Press, 1994), 108.

[213]Kircher, *Vulcano's*, 34.

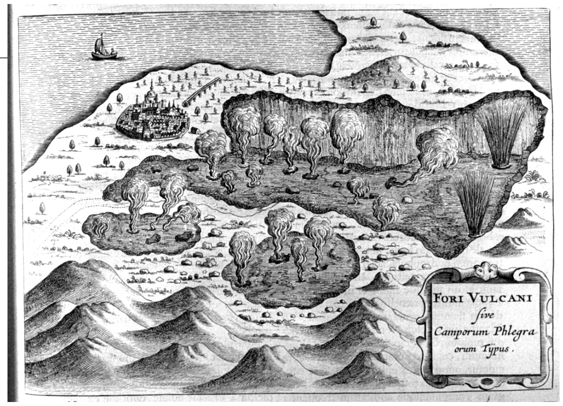

FIGURE 129. *Camporum phlegra*, from Kircher, *Mundus subterraneus*, 1664, 179. HSCI.

Caption. Fori Vulcani sive Camporum Phlegra orum Typus.

In the Phlegraen Fields (Figure 129), Monte Nuovo had formed overnight in 1538, giving vivid demonstration of the power of subterranean fire.

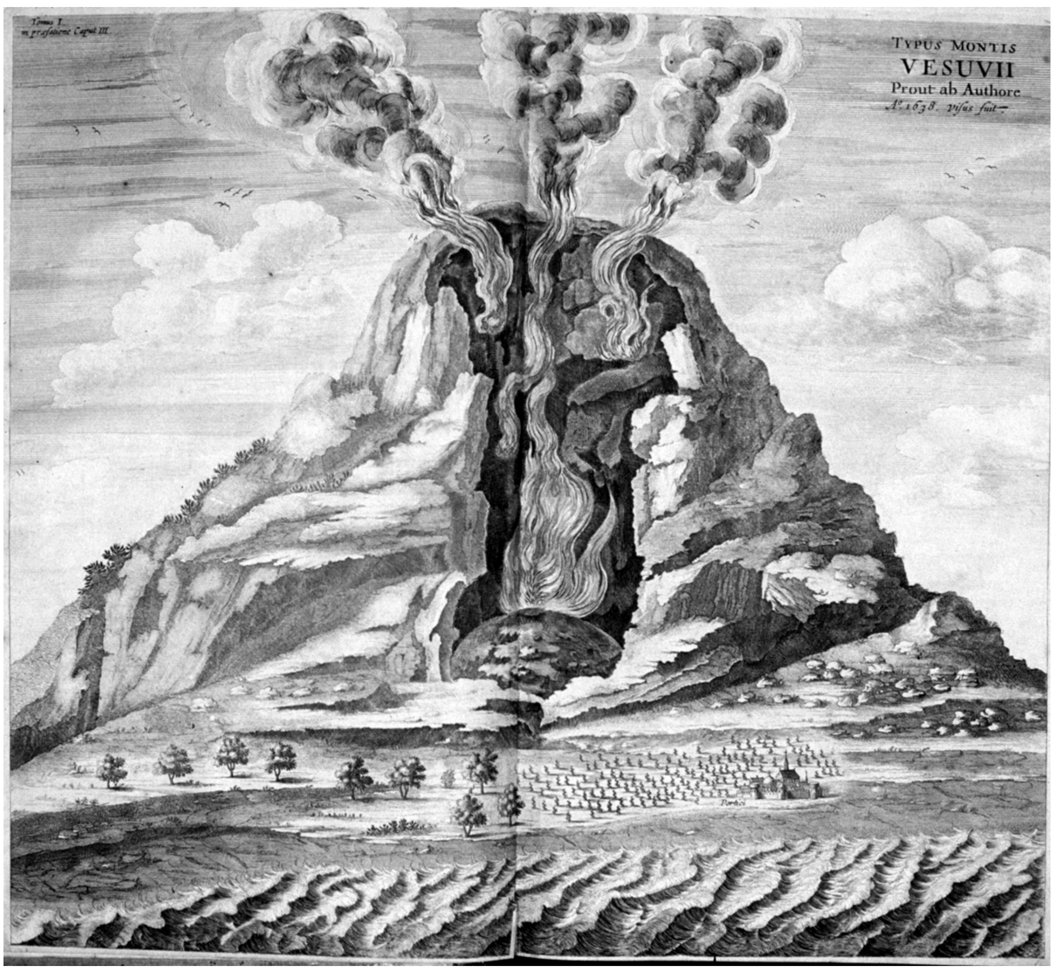

FIGURE 130. Athanasius Kircher, "Praefatio," c. III, *Mundus subterraneus* (1664), Vesuvius. LHL.

Caption. Typus Montis Vesuvii. Prout ab Authore. Anno 1638. Visus fuit.

Kircher included sketches of active volcanos such as Etna, Vesuvius, and Stromboli described on the basis of first-hand observations. During a sea-voyage to Naples in 1638 Kircher witnessed smoke plumes, tidal waves, and the tragic loss of the city of San Eufémia. From the simultaneity of volcanic eruptions Kircher inferred a network of subterranean communications. A personal account of this experience appears in the "Praefatio" of *Mundus subterraneus*. Thus the first double-folo illustration in *Mundus subterraneus* is not one of the global sections, which are the most dramatic and memorable illustrations, but a huge depiction of Vesuvius included in the same preface (Figure 130). With Vesuvius still smoldering, Kircher hired a local guide to ascend with him to the top for the sake of first-hand investigation, and dared to have himself lowered into the crater in a harness to take temperature measurements. It is no wonder that Kircher used Vesuvius as his *Typus Montis*.[214]

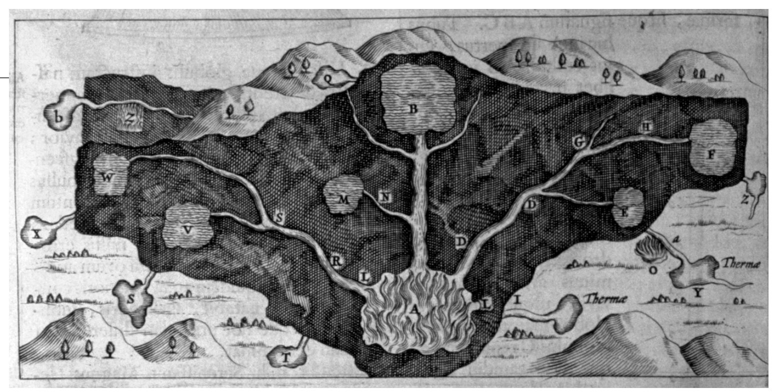

FIGURE 131. *Pyrophylacium* connected by various passageways to *hydrophylacia*. Kircher, *Mundus subterraneus*, 1664, 256. HSCI.

Kircher supposed that chambers within the cavernous Earth called *geophylacia* were created when the dry land was raised above the sea on the third day of creation. Three types of *geophylacia* imprison air, water, or fire within the Earth; these air-houses, water-houses, and fire-houses were called respectively *aerophylacia*, *hydrophylacia*, and *pyrophylacia*, and are often found in various relations (Figure 131).[215]

[214] In addition to the "Praefatio" in *Mundus subterraneus*, the episode is dramatically recounted in Kircher, *Vulcano's*, 35–37. The preliminary sketch and manuscripts are discussed in Gerhard F. Strasser, "*Spectaculum Vesuvii*: Zu Zwei Neuentdeckten Handschriften von Athanasius Kircher mit seinen Illustrationsvorlagen," in *Theatrum Europaeum: Festschrift für Elida Maria Szarota,* ed. Richard Brinkmann, Karl-Heinz Habersetzer, Paul Raabe, Karl-Ludwig Selig and Blake Lee Spahr (München: Wilhelm Fink Verlag, 1982), 363–384.

[215] Literally, *phylake* is a prison or guardhouse.

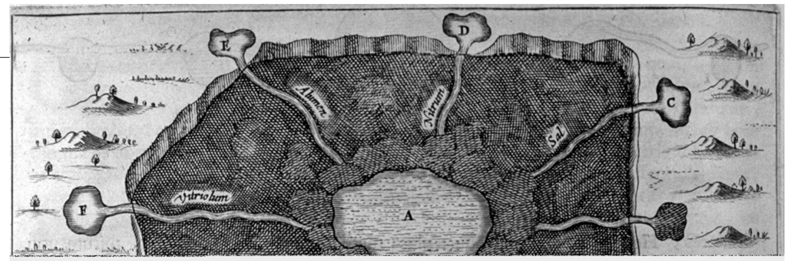

FIGURE 132. Growth of minerals beneath the ground. Kircher, *Mundus subterraneus*, 1664, 258. HSCI.

Another kind of storehouse contains seminal principles responsible for the growth of minerals and earths in passages beneath the ground (Figure 132).

One global section depicts the subterranean circulation of fire through various *pyrophylacia* (Figure 133). The Earth is shown as a furnace of activity, pulsing with subterranean drama beneath the surface world of human habitation. Volcanic plumes embroil the borders with a vivid demonstration of the powerful effects of fire. Thick, turbulent smoke overflows the crust of the Earth, which is shown with a greatly exaggerated vertical scale. Fire is "the life of the Macrocosm, as spiritous blood is of the Microcosm." The largest *pyrophylacium* at the center of the Earth (A) is hell, in Kircher's geocentric cosmos the farthest point from heaven and the prison-house of sinners.[216] Purgatory might be a lesser one nearer the surface (B); in the sulfurous environs of the Phlegraen Fields (Figure 129) Monks living in a monastery reportedly heard beneath their feet the groans of sufferers in Purgatory.[217] Were *pyrophylacia* not providentially circumscribed by water, the entire sublunar realm would burn.[218] The

[216]Kircher, *Vulcano's*, 4. Cf. Figure 150 on page 558.

[217]According to the English editor (not attributed to Kircher), Catholic superstition in the hot, sulphurous environs of the Phlegrean Fields, or Vulcan's Court, held "that the fire underneath, is a part of Purgatory, where departed souls have a temporal punishment. The Fryers that dwell hard by in the Monastery of Saint January, report that they often do hear fearful shreeks and groanings." Kircher, *Vulcano's*, 24.

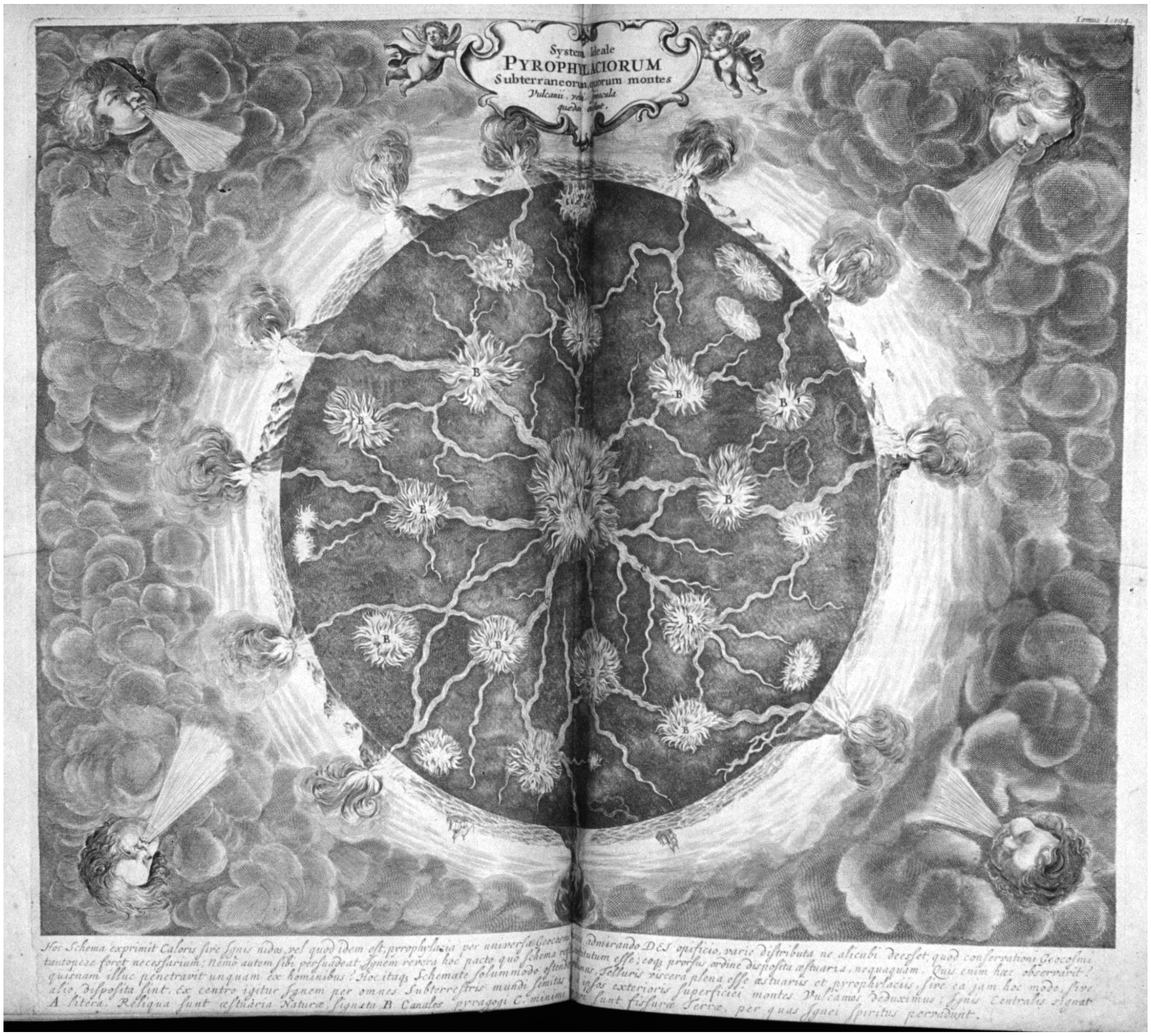

FIGURE 133. Global *pyrophylacia*, or circulation of fire. Kircher, *Mundus subterraneus*, 1664, 180. HSCI.

Caption. Systema Ideale Pyrophylaciorum Subterraneorum, quorum montes Vulcani, veluti spiracula quaedam existant.

[218]"That except it were restrain'd by the encompassing of the Ocean, and the command of the Omnipotent Deity, it would attract and suck in the universal bulk, of all elementary Nature, into an unquenchable combustion, and Conflagration." Kircher, *Vulcano's*, 3. What was hell for Catholics was apocalyptic Conflagration for Protestants. London had burned in 16xx, and Etna erupted in 1650 and 1669. Capitalizing on both of these displays of fiery power, the title page warned of eschatological conflagration: "None sadlier knows the unresisted Ire, / Then Thou, Poor London! of th'all-raging Fire. / But these occasion'd kindlings are but Blazes, / To th' mighty Burnings, which fierce Nature raises. / If then a Town, or Hills blaze be so dire; / What will be th' last, and Universal Fire?" When Burnet later wrote his Theory of the Earth, he echoed the suspicions of many Englishmen before him that in the general conflagration, Rome and Italy, home of the papal anti-Christ, would be the first regions of the Earth to burn.

fire-ducts (C) give rise to hot springs and minerals. Volcanos provide air to the geocosmic circulation and, like alchemical spiracles or chimney furnaces, offer an outlet for fumes rising from

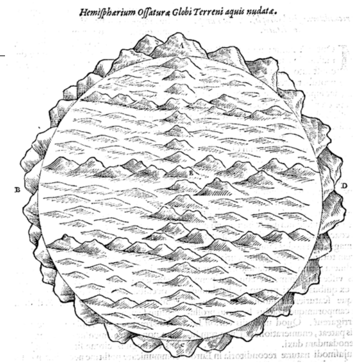

FIGURE 134. Orientation of mountain chains. Athanasius Kircher, *Mundus subterraneus*, 1664, p. 69. HSCI.

Caption. Hemisphaerium Ossaturae Globi Terreni aquis nudatae.

the fires. The mountains like bones of the Earth provide a secure skeletal structure. Kircher even suggested that the geographical orientation of mountain chains was ordered, in that they tend to run north-south and east-west (Figure 134).[219]

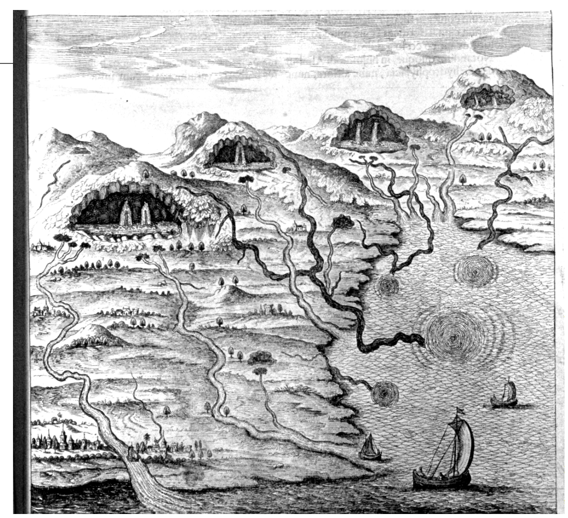

FIGURE 135. Kircher's water cycle. *Mundus subterraneus*, 1664. HSCI.

According to Kircher, *hydrophylacia* lie at the cavernous roots of mountains such as the Alps (Figure 137) and the Andes (Figure 136) where they provide the source of springs and rivers (Figure 135). Many rivers flow in subterranean channels for all or some portion of their course to the sea. Ocean whirlpools, such as the marvellous Norwegian *maelstrom* (Figure 138), mark the submarine entrances of passages (Figure 139) which siphon water from the sea back to the mountainous *hydrophylacia*. Polar views depict the two greatest whirlpools through which water descends into the Earth (Figure 24 on page 180; note the

[219]This claim was immediately disputed by Steno, but the effort to discern geometrical patterns of mountain chains was a perennial topic of Theorists of the Earth up to Elie de Beaumont in the nineteenth century.

mountain chains depicted as running east-west in the northern continents). All of these features are represented in a second composite global section depicting the circulation of water (Figure 140; handcolored versions also exist, see Figure 37 on page 373).

FIGURE 136. Andes with Hydrophylacium

Caption. Tabula qua Hydrophilacium Andium exhibetur, 74.

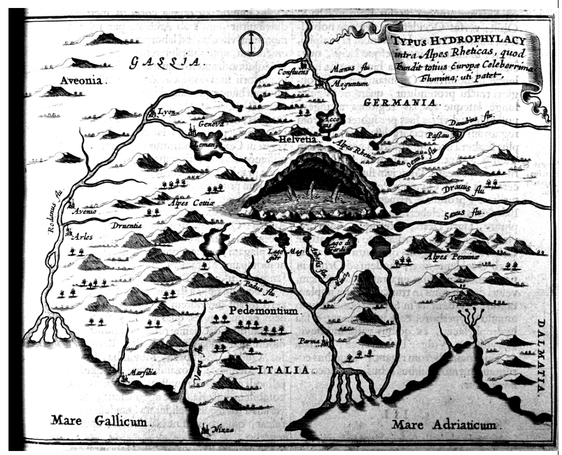

FIGURE 137. Alps with Hydrophylacium, 71.

Caption. Typus Hydrophylacy intra Alpes Rheticus, quod Fundit totius Europae Celeberrima Flumina; uti patet.

FIGURE 138. Norwegian maelstrom. p. 149.

Caption. Descriptio Vorticis Norvegiae et Bodniae eorumque mirabilium effectum, quos in fluxu et refluxu operantur, 149.

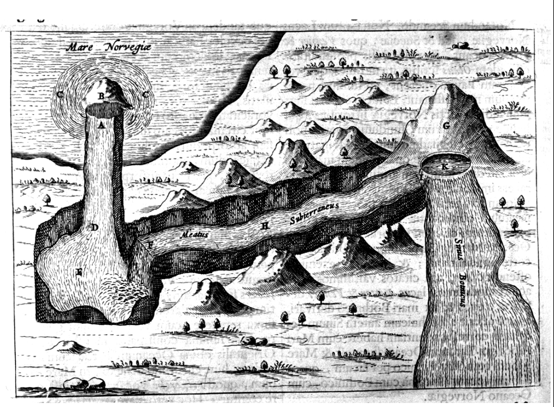

FIGURE 139. Norwegian passageways. Kircher, *Mundus subterraneus*, 1664, p. 148. HSCI.

Explanation. Mare Norvegiae, Meatus Subterraneus, Sinus Botnicus.

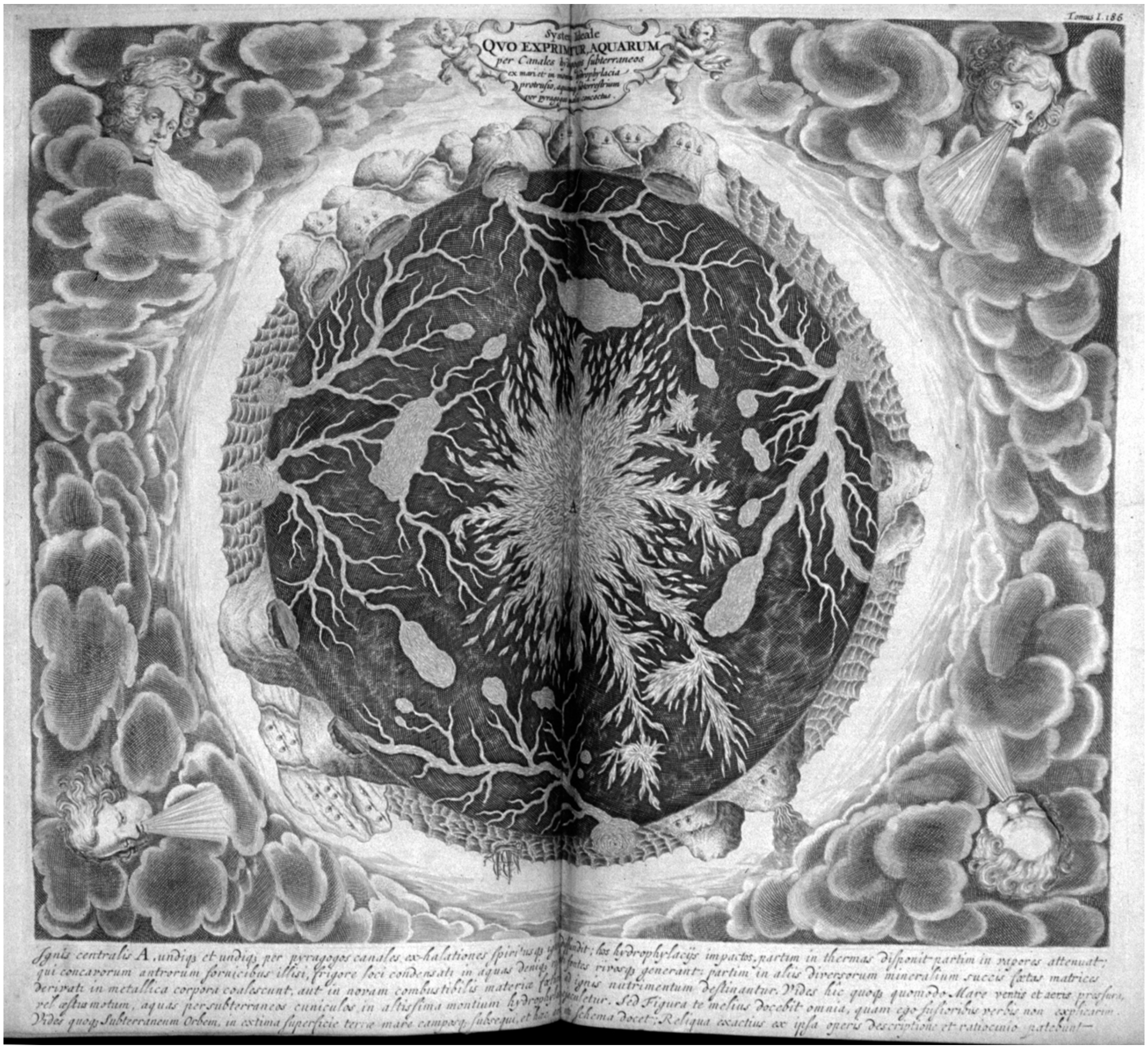

FIGURE 140. Global *hydrophylacia*, or circulation of water. Kircher, *Mundus subterraneus*, 1664, before p. 175. HSCI.

Caption. Systema Ideale Quo Exprimitur Aquarum per Canales hydragogos subterraneos ex mari et in montium hydrophylacia protrusio, aquarumque subterrestrium per pyragogos canales concoctus.

Myriad subterranean channels keep the water in constant circulation through the Earth, nourishing the growth of minerals and communicating with surface seas and lakes. Water descends to *hydrophylacia* near the fiery core, providing needed fuel to sustain the subterranean fires. By means of the pumping of the tides which acts like bellows, water in the channels ascends to reservoirs in high mountains. From these it emerges as rivers and springs and returns to the ocean once again. Fiery exhalations create the winds that keep the seas in motion. Thus "Water, Fire; Fire, Water; mutually, as it were, cherish one another; and by a certain unanimous consent, conspire to the Conservation of the Geocosm, or Terrestrial World."[220]

Regarded as an organic body, a geocosm corresponding to both the universe as macrocosm and the human microcosm, the Earth has become a natural system: "And so in an everlasting, and circulatory motion, all things which are beheld in Nature, do exist and abide."[221] A circulatory system of the Earth required that the subterranean fires not diminish into mere embers over time:

> This one thing only hath, after a wonderful manner, tortur'd the wits of Philosophers hitherto; In that they apprehend not whence the unsatiableness and greedy devouring of the perpetual fire should be supply'd with new and new food alwayes. And how the Pumices, Cinders and Ashes, and the other refuses of burnt matter, should in succession of time be converted into new materials, fit for fires. Which knot, that it may be untied; You remember that before (elsewhere) we shewed; how that to the conservation of Nature in its perpetual & constant course, there was a necessity of an everlasting circulation and return round of things. In the Heavens, the Elements; the Air, Water, Earth, and its several sorts, soils, and Minerals, &c. even with the very Fire also, and its materials and nutriment. As appears in the perpetual wheeling round of the Planets and Stars, by a constant and inviolable Law of Nature, so many thousands of years. The perpetual motion and mutation of the Elements; alwayes unvariable in the greatest variety of things. The perpetual circulation of waters, both within, and about the Earth. All Rivers come from the Sea, and return to the Sea again; as Solomon, the Wise, hath confirm'd to us.[222]

With these global sections Kircher did not pretend to delineate the subterranean world in actual dimensions with quantitative precision. Rather, the sections elucidate the kinds of relations that must hold between the unseen *phylacia*, subterranean passages, and the terrestrial surface. The editor of the English anthology advised the reader that the sections were ideal

[220] Kircher, *Vulcano's*, "Explication of the Schemes," I.

[221] Kircher, *Vulcano's*, "Explication of the Schemes," I. In *Mundus subterraneus* Kircher approvingly cited William Harvey's discovery of the circulation of the blood.

[222] Kircher, *Vulcano's*, 54.

types: "Yet you are not to imagine, that the Fires and Waters, &c. are really thus disposed in Nature underground. For whoever has seen them?"[223] And divine omnipotence might accomplish the same effects through other means. However, the probable existence of such unseen structures could be inferred from their surface manifestations. For example, the quite visible lava flows at Mount Etna indicate a vast subterranean repository, Kircher suggested, on the basis of quantifiable measures:

> Which Torrents indeed of liquid and melted Fire, Histories deliver to have flown and run down sometimes to eighteen miles in length; and sometimes, now one, then two, three, or four miles space in breadth. So that hereupon none can sufficiently admire, from whence such an incredible fertileness of melted matter should take its original; where, and in what places it should have shops, and fusory or melting fornaces, of so great capacity, hidden and laid up underneath, to the liquefaction and melting of so many Minerals and Metals. But as these inaccessible works of God, are most remote from all Sense; so they can never be enough penetrated and pry'd into by any humane Understanding; And it remains only to wonder and admire at, what cannot be conceived of the incomprehensible Majesty of the Divine Works. For if you undertake an account or computation of the melted matter, according to the calculation of divers times; you would find it to grow to such an extravagant heap, that it would far exceed twenty Aetna's, in its bulk.[224]

The sensibility Kircher displayed toward what is rare, admirable, miraculous, or unusual bears little resemblance to the dismal sentiment Burnet harbored toward the mountainous structure of the present globe. To Burnet mountains signified disorder; to Kircher they intimated a fathomless dimension of unsuspected subterranean order. For Kircher, mountains must have been present in the paradisiacal Earth (Figure 125 on page 526), since the system of the Earth could not function without them. In Kircher's Theory the geocosmos was not chaotic, still less a broken and shattered world; rather, it was a plentifully-stocked and well-ordered House. The English editor noted this when he summarized the purpose of depicting invisible structures in the sections:

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[223] Kircher, *Vulcano's*, "Explication of the Schemes," I; note that in the captions above Kircher referred to each global section as a "Systema Ideale."

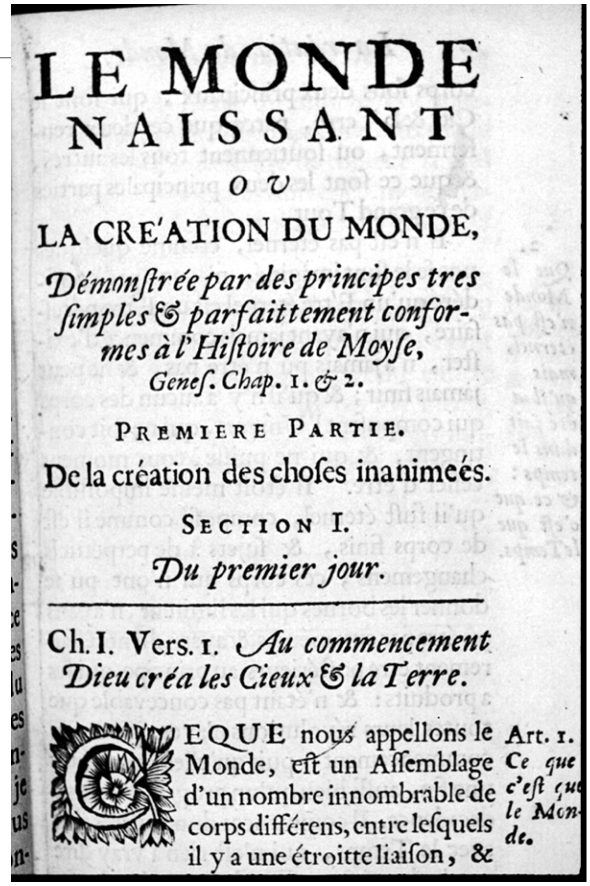
[224] Kircher, *Vulcano's*, 50.

> But this onely was to signifie, according to the best imagination of the Author, that they are after some well-ordered and artificial, or organiz'd way or other, contriv'd by Nature; and that the Under-ground World is a well-framed House, with distinct Rooms, Cellars, and Store-houses, by great Art and Wisdom fitted together; and not, as many think, a confused and jumbled heap or Chaos of things, as it were, of Stones, Bricks, Wood, and other Materials, as the rubbish of a decayed House, or an House not yet made.[225]

Prompted by his first-hand observation of volcanic phenomena, the interpretations of which were correlated with travel accounts and literary reports, Kircher's Theory of the Earth (for so it was regarded by many later writers) was a natural expression of his Jesuit instincts for the integration of new observations within the framework of ancient texts. In addition, the case of Kircher refutes the suggestion that Theories of the Earth presupposed the adoption of Cartesian cosmology or a mechanistic natural philosophy. Kircher's Theory of the Earth was nurtured by his geocentrism because Kircher viewed the Earth as a noble object of study: in defense of Jesuit tradition the best complement to an enthusiastic tour of the Tychonic heavens in *Itinerarivm Exstaticvm* was an equally rewarding and more extended tour through the subterranean world.

[225]Kircher, *Vulcano's*, "Explication of the Schemes," I.

§ 9-iii. The Cartesian-Hexameral Birth of the World


LE MONDE
NAISSANT
OV
LA CRE'ATION DU MONDE,
Démonſtrée par des principes tres ſimples & parfaittement confor-mes à l'Hiſtoire de Moyſe,
Geneſ. Chap. 1. & 2.

PREMIERE PARTIE.

De la création des choſes inanimeés.

SECTION I.

Du premier jour.

Ch. I. Vers. 1. *Au commencement Dieu créa les Cieux & la Terre.*

CEQUE nous appellons le Monde, eſt un Aſſemblage d'un nombre innombrable de corps différens, entre leſquels il y a une étroitte liaiſon, &

Art. 1. *Ce que c'eſt que le Monde.*

FIGURE 141. Part I first page, Barin *Le Monde Naissant*, 1686

That philosophers like Kircher, a Jesuit, or Becher, a chymist, related their schemes to the hexameral tradition is not surprising. On the other hand, it may not seem obvious that the hexameral tradition would play a significant role in seventeenth-century mechanical philosophy.[226] Yet in *Le monde naissant*,[227] published in Utrecht five years after Burnet's *Telluris Theoria Sacra*, Théodore Barin harmonized Cartesian cosmology with scripture, and he did so in a manner utterly different than Burnet. Barin expounded Cartesianism within a hexameral framework "perfectly conforming to the History of Moses" (Figure 141), and even deployed Cartesianesque diagrams to illustrate the creation week. Moreover, Barin can be read as attempting to follow Descartes' lead, and his endeavor was arguably more consistent with Descartes' original presentation of his physics than was Burnet's appropriation of Cartesian-

[226]Many scholars have cautioned against drawing a clear distinction between the mechanical philosophy and various chymical philosophies, for the two were frequently reconciled in the seventeenth century in ways that render abstract use of the categories of little use. A classic argument along these lines is Allen G. Debus, "Thomas Sherley's *Philosophical Essay* (1672): Helmontian Mechanism as the Basis of a New Philosophy," *Ambix* 27 (1980): 124–135; recent Boyle studies reinforce the point, cf. Lawrence M. Principe, *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton: Princeton University Press, 1998).

[227]Barin, Théodore. *Le Monde Naissant, ou La Creation du Monde, Démonstrée par des principes tres simples & tres conformes à l'Histoire de Moyse, Genes. chap. I & II.* Utrecht: Pour la Compagnie des Libraires, 1686.

ism in service of the deluge. Writing to Mersenne in 1641, Descartes suggested that "There will be no difficulty, so far as I can see, in adapting theology to my style of philosophizing." He then explained that he planned to submit his explanations of transubstantiation and the first chapter of Genesis to the Sorbonne for examination, and afterward include them in the *Principia Philosophiae*.[228]

Controversies in Utrecht intervened,[229] however, and Descartes adopted a different strategy. By the time the *Principia Philosophiae* appeared in 1644 an explanation of the first chapter of Genesis was nowhere to be found. The *Principia* was shorn of any appearance of theological offense, Descartes studiously avoiding the theologian's prerogative of interpreting scripture and carefully shielding himself with repeated attestations of the subjection of physical hypotheses to theological truths which depend on divine omnipotence.[230] It was not enough: despite his attempted circumspection, enduring controversies over Descartes' physics

[228]"There will be no difficulty, so far as I can see, in adapting theology to my style of philosophizing. I do not see that anything in it needs changing except in the case of transubstantiation, which is very clear and easy to explain on my principles. I shall have to explain it in my *Physics*, along with the first chapter of Genesis; I propose to send my explanation to the Sorbonne to be examined before it is printed." Letter to Mersenne, 28 January 1641; AT III: 295-296, trans. Cottingham, 3: 172. One can imagine a Sorbonne theologian desiring rather that Descartes adapt his philosophy to the Sorbonne style of theologizing rather than expecting the Sorbonne theologians to change their account of transubstantiation to suit Descartes' philosophy. Letter to [Boswell?, 1646?]: "Parum quidem progredior, sed progredior tamen; sum iam in describenda natiuitate mundi, in qua spero me comprehensuram maximam Physicae partem. Dicam autem me, relegendo primum caput Geneseos, non sine miraculo deprehendisse, posse secundum cogitationes meas totum explicari multo melius, uti quidem mihi videtur, quàm omnibus modis quibus illud interpretes explicuerunt, quod antehac nunquam speraueram: nunc vero, post nouae meae Philosophiae explicationem, mihi propositum est clare ostendere illam cum omnibus fidei veritatibus multo melius consentire, quàm Aristotelicam." Letter to [Boswell(?), 1646(?)], AT IV: 698. Now attributed to 1630, October 14, which better fits the chronology of Descartes' changing views on Genesis 1 related here; see AT revised edition IV: 816. Ariew argues against conventional interpretations of Descartes' debates on transubstantiation which picture him as a reluctant participant, dragged into an unwanted dispute against his will. Roger Ariew, *Descartes and the Last Scholastics* (Ithaca: Cornell University Press, 1999), chapter 7, "Descartes and the Jesuits of La Flèche: The Eucharist." It would be an analogous mistake to interpret Descartes' interest in reconciling his philosophy with the hexameral tradition as a later, unwanted distraction from his true interests.

[229]Cf. Theo Verbeek, *Descartes and the Dutch: Early Reactions to Cartesian Philosophy, 1637-1650* (Carbondale: Southern Illinois University Press, 1992). Two recent biographies offer a brief account and references to the relevant literature: Stephen Gaukroger, *Descartes: An Intellectual Biography* (Oxford: Clarendon Press, 1995), ch. 9, and Geneviève Rodis-Lewis, *Descartes: His Life and Thought,* trans. Jane Marie Todd (Ithaca: Cornell University Press, 1998), ch. 5. None of these mention Théodore Barin.

[230]Regarding theology and divine omnipotence, Descartes insisted that he did "not take it upon myself to use the power of human reason to settle any of those matters which depend on the free will of God." AT VII, 153. Quoted in Gaukroger, 356.

and the Eucharist belied the simple optimism expressed by Descartes in 1641.[231] Theological controversy on this point immediately ensued and persisted into the latter half of the century:

> In 1663 the works of Descartes were placed on the *Index librorum prohibitorum*; in 1671 the king and the University of Paris issued decrees forbidding the teaching of Cartesian philosophy, while the *Parlement* of Paris was considering a similar measure; and in 1680-81 a number of well-known and important religious figures published anti-Cartesian treatises. In all three episodes the issue of the Eucharist was central in the attacks leveled against this philosophy.[232]

Although critical, the Eucharist was not the sole issue. Controversy over the interpretation of Genesis 1 played a significant role as well in the reception of Cartesianism, and often the two issues were linked. This linkage is evident in the case of Anne-Marie de Schurman (b. 1612), who closely followed the controversies around 1640 in the Low Countries about Cartesian philosophy.[233] Descartes reported to Anne-Marie de Schurman that he had attempted to learn Hebrew in order to study the first chapter of Genesis in its original language, although by this time he had given up the attempt, concluding that the text was metaphorical, without clear and distinct propositional content of relevance to physics.[234] This abandonment of hexameral presentation by Descartes shaped the response of Anne-Marie de Schurman: it was not only the Eucharist but also Descartes' metaphorical interpretation of Genesis 1, *i.e.*, the disjunction of his philosophy from hexameral idiom, which led Schurman to "distance my heart from the profane man."[235]

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[231]See Richard A. Watson, "Transubstantiation Among the Cartesians," in *Problems of Cartesianism*, ed. Thomas M Lennon, McGill-Queen's Studies in the History of Ideas, ed. Richard H. Popkin (Kingston and Montreal: McGill-Queen's University Press, 1982), 127–148; Ronald Laymon, "Transubstantiation: Test Case for Descartes's Theory of Space," in *Problems of Cartesianism*, 149–170; and Steven M. Nadler, "Arnauld, Descartes, and Transubstantiation: Reconciling Cartesian Metaphysics and Real Presence," *Journal of the History of Ideas* (1988): 229–246. Roger Ariew, *Descartes and the Last Scholastics* (Ithaca: Cornell University Press, 1999), chapter 7, "Descartes and the Jesuits of La Flèche: The Eucharist."

[232]Nadler, 238.

[233]Descartes bemoaned her loss to his side in a letter to Mersenne, 11 November 1640: "Voetius [Gisbert Voetius, 1589-1676] and the other professors [at the University of Utrecht] have done all they can to get the magistrates to forbid him [Henri le Roy, Henricus Regius] to teach; but despite their efforts, the magistrates allow him to continue. This Voetius has also spoilt Mlle de Schurmans: she had excellent gifts for poetry, painting and other gentle arts, but these last five or six years he has taken her over so completely that she cares for nothing but theological controversies...." AT III: 231; trans. Cottingham, 156.

Just as Cartesian sympathizers such as Antoine Arnauld argued for the compatibility of Cartesian physics with the Eucharist, so the legitimation of Cartesian philosophy in the eyes of seventeenth-century Roman Catholics required its reconciliation with Genesis 1, and Cartesian harmonizers took up the unfinished task.[236] For example, in 1668 the Cartesian philosopher Louis Géraud de Cordemoy (d. 1684) argued in a public letter that Genesis 1 was consistent with Cartesian philosophy.[237] In *Cartesius Mosaïzans*, published the following year, Joannes Amerpool attempted to demonstrate the complete harmony of Genesis 1 with Descartes' vortices-based cosmology.[238] And only five years after the anti-Cartesian treatises of 1680-81 referred to by Nadler, Théodore Barin was sufficiently confident of his harmoniza-

[234]"M. Descartes la vint voir chez elle à Utrecht, et comme il se passa quelque chose de particulier en leur conversation, dont Mlle de Schurmann a voulu laisser quelque mémoire, je crois que je ferai bien de le rapporter icy fidélement. Il la trouva livrée à son étude favorite, qui étoit celle de l'Ecriture sainte, d'après le texte original en hébreu. Descartes fut étonné qu'une personne de ce mérite donnât tant de temps *à une chose de si peu d'importance*: ce furent les termes mêmes dont il se servit. Comme cette demoiselle cherchoit à lui démontrer l'importance capitale de cette étude pour la connoissance de la parole divine, Descartes lui répondit que lui aussi avoit eu cette pensée et que dans ce dessein il avoit appris cette langue qu'on appelle sainte, qu'il avoit même commencé à lire dans le texte hébreu le premier chapitre de la *Genèse*, qui traite de la création du monde; mais que, quelle que eût été la profondeur de ses méditations, il avoit eu beau réfléchir, il n'y avoit rien trouvé de clair et de distinct, rien qu'on pût comprendre *clarè et distinctè*. Alors s'étant aperçu qu'il ne pouvoit point entendre ce que Moïse avoit voulu dire, et même qu'au lieu de lui apporter de nouvelles lumières, tout ce qu'il lisoit ne servoit qu'à l'embrouiller davantage, il avoit dû renoncer à cette étude." Adams and Tannery, IV: 700-701, "*Vie de Jean Labadie*, 1670. Cité par Foucher de Careil, p. 150-152, *Descartes et la Princesse Elisabeth*. Paris, Germer-Baillière, 1879."

[235]Labadie continues: "Cette réponse surprit extraordinairement Mlle de Schurmann; elle la blessa profondément, et elle en conçut une telle antipathie contre ce philosophe, qu'elle évita depuis ce jour de jamais se trouver en relation avec lui. Dans le journal où elle fait mention de cet événement, elle avoit mis à la marge sous ce titre: '*Bienfaits du Seigneur,*' les paroles suivantes: 'Dieu a éloigné mon coeur de l'homme profane, et il s'est servi de lui comme d'un aiguillon pour ranimer en moi la piété, et pour me faire me donner entièrement à lui.'" AT IV: 700-701, "Vie de Jean Labadie, 1670. Cité par Foucher de Careil, p. 150-152, *Descartes et la Princesse Elisabeth*. Paris, Germer-Baillière, 1879."

[236]Bouillier aptly notes that "Pour repousser les attaques des péripatéticiens, quelques cartésiens imaginèrent de prouver que Descartes était dans Aristote; de là plusieurs essais de philosophie péripatético-cartésienne. S'il était utile de chercher à montrer que Descartes avait péripatétisé, il l'était plus encore de chercher à montrer qu'il était d'accord avec la Bible, et même qu'il avait mosaïsé." Francisque Bouillier, *Histoire de la Philosophie Cartésienne*, 2 vols. (Paris: Impression Anastaltique, 1868), 1: 285. Of course, the motion of the Earth remained another point of contention, despite Descartes' insistence that technically the Earth lies at rest within its moving vortex (cf. *Principia Philosophiae* Part III, Questions 18, 19, 28, 29, and Part IV Question 22). Gaukroger argues as well that Descartes' metaphysics was designed to legitimate Cartesian natural philosophy; cf. Stephen Gaukroger, *Descartes: An Intellectual Biography* (Oxford: Clarendon Press, 1995), 355.

[237]AT note, V: 169: *Copie d'une Lettre écrite à un sçavant Religieux de la Compagnie de Jesus* to show, in part, that "tout ce qu'il en a écrit semble estre tiré du premier Chapitre de la Genese," dated 5 November 1667, published in 1668, attributed to Cordemoy by AT and written to P. Cossart; V: 169. For example, according to Descartes, light (as the primary element) existed before the formation of the Sun. Cordemoy, *Ouvres philosophiques*, ed. Clair-Girbal, 1968, 258ff. Cited in Geneviève Rodis-Lewis, "From Metaphysics to Physics," in *Essays on the Philosophy and Science of René Descartes,* ed. Stephen Voss (Oxford: Oxford University Press, 1993), 256.

tion with Roman Catholic theology to use Descartes' natural philosophy as the key for interpreting Geneis 1.

TABLE 54. Explanation of Figure 142, Creation of the Heavens and the Earth

	Explanation
A	Center of a rotating globe of subtle matter (the primary element), violently agitated
B	Envelope around the core
C	Interior of the Earth, a second layer or "skin" around the core
E	Waters covering the entire globe
F	Air, the surrounding expanse
G,H,I,K	Subtle matter (the same as within the globe) also comprises the environment of the stars

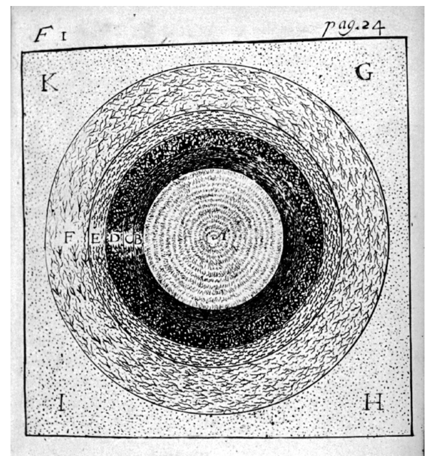


FIGURE 142. Barin *F I*, p. 24. Genesis 1:1, First day

Barin argued from the text of the first day that the heavens (or vortices) and the Earth had a beginning in time, and are neither eternal, immutable, nor were they created in an instant. In the beginning God created a finite quantity of the prime matter from which all bodies would derive.[239] By the end of the first day, the resulting elements in the region of the Earth settled into concentric layers ABCDEF, illustrated in a meteorological (not cosmic) section reproduced as Figure 142.[240] At this point, following the Genesis account, Barin's narra-

[238]Joannes Amerpool, *Cartesius Mosaïzans* (Lewarden, 1669). I have not seen a copy of this work. Cited in Bouillier, 285. AT note, V: 169: *Cartesius Mosaîzans, seu Evidens et facilis conciliatio Philosophiae Cartesii cum historiá Creationis primo capite Geneseos per Mosem traditâ.* Johanne Amerpoel Groningâ-Frisio. Leovardiae, Pro Haeredibus Thomae Luyrtsma, 1669.

[239]The universe was not infinite in Barin's interpretation of Descartes' "indefinite."

[240]"....l'ayant répandu tout autour de la terre, qui'il en couvrit comme d'une grande toison, il en acheva ainsi la premiere ébauche, comme vous le pouvés voir en cette Figure, où A, représente le centre & le fond de son Globe, composé de la matiere tres subtile, ou du premier Élément, qui y tourne en rond; B, la permiere enveloppe que nous ne connoissons point; C, la seconde écorce, ou la Terre interieure: E, les Eaux, qui d'abord la couvroient toute; F, l'Air qui est épandu tout autour; G, H, I, K, la matiere subtile dont son globe ainsi composé estoit tout environné." Barin, 24.

tive is geocentric, concerned only with events in the region of the Earth rather than describing events with reference to the center of the universe.

The second verse revealed that the Earth was without form and void, meaning that the Earth as yet had no metals, rocks, or other ornaments, but was a confused mass. It was an abyss because of its vastness and bottomless immensity, and dark because of its obscurity. The Spirit brooded over it, warming and agitating it to dispose it toward the production of what would follow.[241]

With the "Let there be light" of the third verse, the matter began turning in response to the divine command. This motion produced light. The Earth was now situated in a large vortex with annual motion, as illustrated in Figure 143.[242] Due to the pressure of the vortex, tides appeared on the sides of the Earth away from the center (cf. Figure 147 on page 552). When God separated the light from the darkness, according to verse 4, Barin glossed the text by explaining the nature of light and colors, and how they are produced. In verse 5 God called the light day, and the dark night. For Barin, this was the beginning of diurnal revolution and the end of the first day, as illustrated with the formation of a small vortex around the Earth in Figure 144.[243]

[241]Barin, 24.

[242]"On le comprenda aisément par la Figure suivante, dans la quelle A, A, A, A, est le gros de la matiere subtile, non encore débrouïllée, & confuse. B, B, B, B. est la portion de cette même matiere, qui tourne en rond, & qui fait un Tourbillon. C, est le centre cet Orbe, ou de ce Tourbillon, D, D, D, D, en est la Circonférence. T, est la Terre, qui est proche de cette circonférence. E, E, E, E, Sont les lignes droittes que forment les petites boules de la matiere subtile, qui tendent à s'éloigner du Centre du Tourbillon, autour duquel elles se meuvent. F, F, est la moitié du globe de la Terre, qui est tournée vers ce même centre, & vers laquelle tendent plusieurs de ces lignes droittes, ou de ces rayons. G. est le milieu de cet hémisphére. Car il est evident qui si sur cet Hémisphere il y avoit eu un oeil en quelque endroit comme en G, il n'auroit pas manqué d'y recevoir l'impression du mouvement de ces globules, qui y auroit remué les filets de la retine, & d'en êtré éclairé." Barin, 29.

[243]"C'est ce que l'on peut voir clairement dans la Figure suivante, où A, est le grand Tourbillon, prés de la circonférence duquel Dieu placea la Terre. B, C, D, E, marquent le sens selon lequel ce grand Tourbillon tourne continüellement autour de son centre. T, le globe de la Terre, a, a, le petit Tourbillon formé autour d'elle, b, c, d, e, le sens selon lequel il tourne, & fait tourner la Terre avec luy; f, g, h, l'hémisphere de la Terre, qui est illuminé, h, i, f, l'hémisphére ténébreux, qui luy est opposé, f, g, h, i, le sens selon lequel le globe de la terre tourne, étant emporté par la matiere subtile de son petit Tourbillon." Barin, 41.

TABLE 55. Explanation of Figure , "Let there be light," or Annual motion

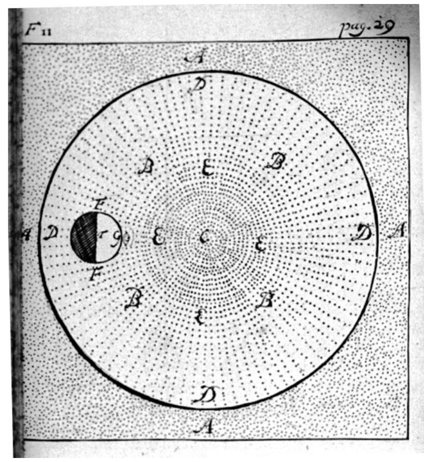
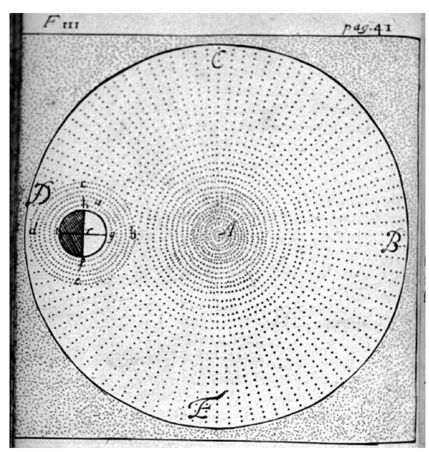
	Explanation	
A	The main part of subtle matter, in a state of confusion, not yet clear or transparent.	
B	A portion of the same subtle matter, which begins turning around and thereby creates a vortex.	
C	The center of the vortex.	
D	The circumference of the vortex.	
T	The Earth, which is near the circumference.	
E	Lines, or rays of light, formed from small balls of subtle matter, tend to move away from the center of the vortex.	
F-F	Marks the two hemispheres of the Earth according to their orientation to the rays of light E.	
G	The Earth's hemisphere which is turned toward the center of the vortex.	**FIGURE 143.** Barin, F II, p. 29. Genesis 1:3, First day

TABLE 56. Explanation of Figure 144, Separation of Day and Night

	Explanation	
A	Center of the great vortex containing the Earth near its circumference.	
B, C, D, E	The direction in which the great vortex rotates around its center.	
T	The Earth	
a, a	The small vortex formed around the Earth	
b, c, d, e	The direction in which the small vortex rotates around the Earth	
f, g, h	The illuminated hemisphere of the Earth	
h, i, f	The darkened hemisphere of the Earth	
f, g, h, i	The direction in which the Earth turns, carried by the subtle matter of the small vortex.	**FIGURE 144.** Barin, F III, p. 49. Genesis 1:4, end of first day.

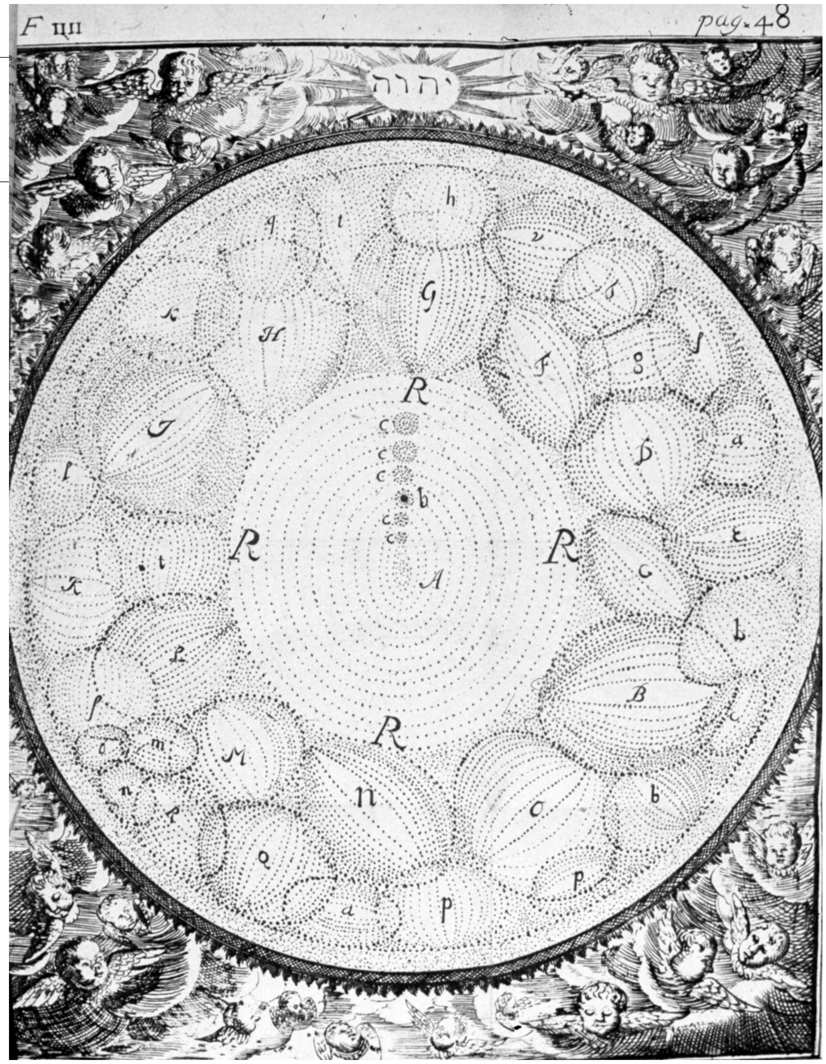


FIGURE 145. Barin *Fig. IIII*, p. 48; Second day. LH.

Description. Cosmic section showing multiple vortices to interpret Genesis 1:6, the divison of the waters.

During the second day, according to verse 6, God stretched out a firmament or expanse, and separated the waters above the firmament from the waters below. Barin exposited this verse through an elaborate diagram of a full cosmic section, as shown in Figure 145. For Barin, the firmament (R; l'Étenduë) is nothing but the boundary between the great vortex of the Sun ("le grand Tourbillon," centered on point A) and the surrounding vortices (designated by a variety of letters in the diagram). Thus the outer surface of the great vortex or "waters below" separates them from the "waters above," which are simply the neighboring vortices. Although the text of Genesis relates events in an orderly succession, these other "orbes" were created at the same time as the Sun's great vortex, from the same kind of material, establishing a due order and balance between them. Within the great vortex itself are small vortices ("petits Tourbillons," C), which all move in the same direction around A, taking a longer time the greater their distance from the center. On the fourth day these will be filled with planets and their satellites, and the Sun will consolidate in the middle of the grand Tourbillon (Figure 146). The vortex of the Earth and its Moon are shown in Figure 145 as *b*. Accompanying YHWH in the empyrean heaven beyond the "waters above," cherubs (traditionally created on the first day) observe the creation of the world. Barin triumphantly concluded that according to Descartes' cosmology heaven is literally true, a fact which could not be more clear than from a Cartesian exegesis of the first two days.

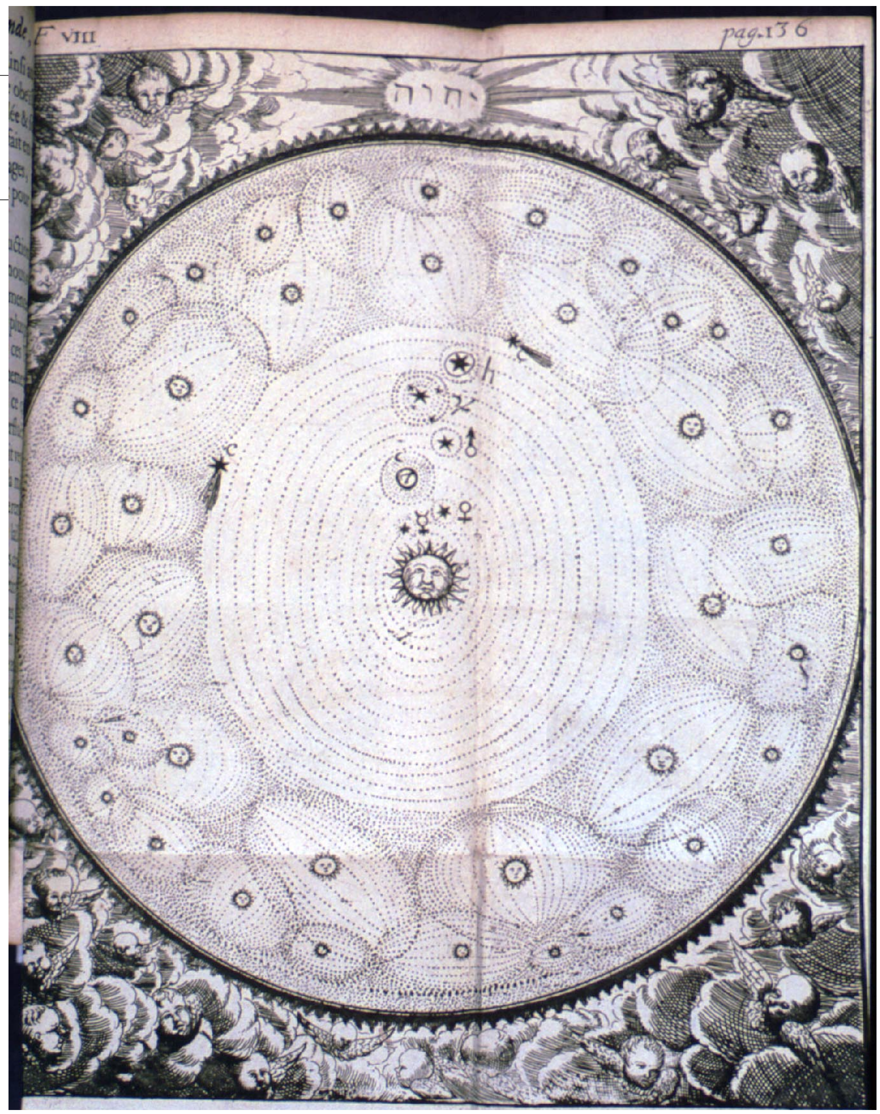


FIGURE 146. Barin, *Fig. VIII*, p. 136, Fourth Day. LH.

Description. Cosmic section with Sun, Moon, planets, and stars.

The hexameral tradition was significant to those who looked to it for guidance, while at the same time it proved plastic in the hands of those who relied upon it. Both Gabriele Beati[244] and Théodore Barin relied upon the hex-

[244]Cf. "The Tychonic-Hexameral Cosmic Vision of Gabriele Beati," beginning on page 418.

ameral text to organize their exposition of cosmology. Both agreed that the heavens are fluid, at least in part. In contrast to Beati's geocentric Tychonic section, however, Barin's diagram depicted a heliocentric solar system (vortex) with all of the planets (including the Earth) revolving around the Sun, and the solar system surrounded not by a sphere of fixed stars but by myriads of other solar systems. Their exegesis of the firmament was quite different, since Beati placed the outer edge of the firmament beyond the fixed stars at the border of the Empyrean heaven, and Barin placed the firmament between the Earth and the fixed stars, far from the Empyrean.

These differences are easily intelligible given Barin's allegiance to Cartesian philosophy, if one compares Barin's account so far with a few clues from Descartes' *Principia Philosophiae* about the shape Descartes' account of Genesis 1 might have taken in the early 1640s. Regarding the creation of the heavens, Descartes raised the question, when discussing the motion of a comet through a vortex, "whether the fixed Stars are seen in their true locations; and what the Firmament is."[245] From Earth the fixed stars are not seen in their true locations, Descartes reasoned, because their rays would be refracted at the edges of neighboring vortices. Indeed, due to refraction at the boundaries of vortices the same star might appear to us at more than one location in the night sky. Descartes referred to the refracting surface of the Sun's vortex as the *Firmamentum*, and Barin has merely followed his lead.[246] Compared with Beati's Jesuit tradition, although Descartes retained a division of the universe into three heavens, by emphasizing the integrity of the vortex system of the Sun he dispensed with the "meteorological heaven" to count the Sun's vortex in its entirety as the "first heaven." For the other two heavens Descartes' numeration was not far different from earlier views which included the starry firmament as part of the second heaven and counted the empyrean as the third

[245]Descartes, *Principia Philosophiae*, Q. 131; Descartes, 160-161 (Adams and Tannery VII: 182).

[246]"Inasmuch as the places in which the stars are thus visible remain constant, and appear not to have changed during the time Astronomers have been observing them, it seems to me that the Firmament is to be understood as nothing other than these surfaces which separate the vortices from one another, and which cannot be altered without the apparent positions of the Stars changing too." Descartes, 161.

heaven. Descartes wrote that neighboring vortices are the second heaven. Descartes did not refer to the supercelestial waters in the *Principia*, but Barin's conjecture that the "waters above" are the vortices above the firmament seems to be consistent with the spirit of Descartes' definition of the firmament, since they do not differ in composition from the "waters below" (i.e., the Sun's vortex), and are similarly fluid rather than solid. The third heaven, unseen in this life and therefore not an object of physics, comprises "all that is beyond," as immense in comparison to the second heaven as the second heaven is greater than the first.[247] In commenting on this passage of the *Principia* in his *Conversation with Burman* Descartes referred to the third heaven as the empyrean, the traditional habitation of God, angels, and the elect (as depicted in the border of Barin's cosmic section), possibly existing somehow beyond ordinary space itself.

Barin's exposition shows how it was possible to read and represent Descartes' cosmology in a traditional way even when appropriating some of the very features of Cartesian philosophy which radically undermined the Ptolemaic cosmos. For example, Descartes explained that the present "first heaven" was previously divided into fourteen or more vortices, which collapsed to form our Sun's major vortex as their stars became covered with sunspots and were transformed into planets.[248] This special feature of the Sun's vortex is evident by the unique status accorded it in Barin's diagram, where it is larger than other vortices, and most conventionally, occupies a central location. Nor did Barin depict the immensity of the second heaven compared to the first heaven, nor the vastness of the empyrean compared to the second heaven. In Barin's depiction the empyrean comprehends and therefore limits the second heaven, making the physical universe finite. By compositional effects like these, both Beati's and Barin's diagrams appear traditional even when presenting non-traditional cosmologies.

[247]Part III, Q. 53, 110-111; cf. "The Tychonic-Hexameral Cosmic Vision of Gabriele Beati," beginning on page 418.

[248]Descartes, *Principia Philosophiae*, Part III, Q. 146; Descartes, 171.

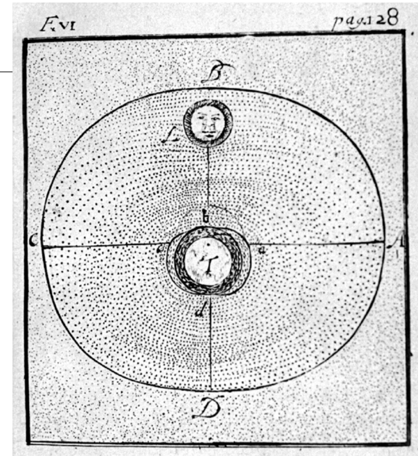


FIGURE 147. Barin F VI, p. 28, Gathering of the Waters and the formation of the Tides

When the text came to the separation of the dry land from the water on the third day, Barin devoted 40 pages to his exposition of the formation of the Earth.[249] Barin illustrated the second half of the verse, on the gathering of the waters to form the oceans, with a Cartesian-like diagram of the tides (Figure 147).[250] The dry land appeared above the water due to a sudden collapse and subsidence of the crust, as illustrated in Figure 148.[251] Ocean floors, caverns, valleys, mountains and rivers all formed at the same time, in the same event, as a result of the same cause, on this day.

[249]Barin, 57-97.

[250]Barin, 62.

[251]"C'est ce que nous avons tâché de représenter autant qu'il se peut, dans la Table suivante. Où A, est la matiere tres subtile qui compose le fond du globe de la Terre, B, est la premiere Enveloppe: C, la Terre metallique; D. est un de ces Abymes, que la Terre extérieure à creusé en s'affaissant; I. sont les exhalaisons qui sortirent lors qu'elle s'affaissa ainsi; E. est un de ces canaux soûterrains, qui furent faits dans la même Terre, au même temps que ces abymes: F. un de ces côtaux, & un de ces vallons, qui se formerent aussi dans le même instant: G. Une grande montagne, avec ses cavernes: H. un écueil dans la mer, ou une Isle." Barin, 60-61.

TABLE 57. Explanation of Figure 148, Appearance of the Dry Land

	Explanation
A	Subtle matter at the Earth's core
B	The first envelope around the core
C	Metallic earth
D	Oceans scoured out or created by the subsidence of the crust
E	Subterranean channels
F	Coasts and valleys
G	A tall mountain, with caverns
H	A reef or an island
I	Exhalations going out of the sub-sided areas

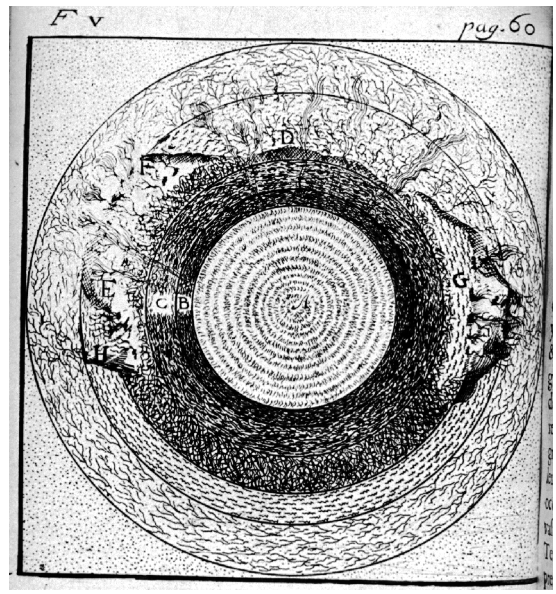
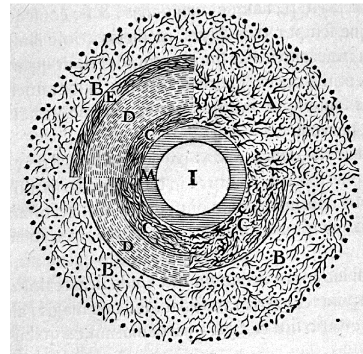


FIGURE 148. Barin F V; Genesis 1:9, Third day, p. 60.

All of this is in exact correspondence to Descartes' cosmogonic hemisections discussed above (cf. Figure 102 on page 476). Yet in the *Principia Philosophiae* Descartes maintained a careful ambiguity regarding the chronology of these events and any possible correspondence with the first three days of the Genesis creation account. The settling of the elemental layers, which Barin assigned to the first day, is regarded by Descartes as a gradual process.[252] Yet apparently, even for Descartes, a long time was not required for the initial formation of the Earth's crust. Referring to his comet-to-planet section, Descartes explained:

[252]Descartes, 200-201.

> And a long time was certainly not necessary for the highest region A [*atmosphere*] of the Earth to be divided into two bodies B [*air*] and C [*Earth's interior crust*]; nor indeed for many fairly long particles to accumulate around D [*water*]; nor, finally, for the first interior shell of body E [*Earth's exterior crust*] to be formed.[253]



This description, as Descartes' readers would have noted, allowed them to assign these events to the beginning of the creation week, as did Barin. However, Descartes implied that the processes leading up to the crustal collapse, which Barin assigned to the third day in order to separate the dry land and the oceans, would not have been possible in two or three 24-hour days:

> But only in the space of many years could the particles of body D have been reduced to the two types described a short while ago [*flexible eel-like sweet-water particles and inflexible spear-like salt-water particles*], and all the shells of body E [*i.e., layers of the Earth's exterior crust*] be formed.[254]

A seventeenth-century interpreter of Genesis might resolve this kind of difficulty by several strategems. First, one could ignore it, as did Barin. Second, like William Nicholls, there was the conventional method of accelerating the natural processes by divine power so that they occurred either in an instant or, perhaps, within 24 hours. Third, more daringly in Counter Reformation Europe, one might lengthen the creation week indefinitely by interpreting all of the days as referring to much longer periods (this was Descartes' own inclination, as shown below). If one desired, like Isaac Newton, the creation week could be lengthened more conservatively by expanding the duration of only the first day or first three days (before the creation of the Sun and Moon on the fourth day) or, like William Ames, by designating six noncontiguous 24-hour days as the times of initiation of each day's work. Fourth, still more radically, one could assign the crustal collapse to the deluge instead of the creation week (as

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[253]Descartes, *Principia Philosophiae*, Q. 39; Descartes, 199-200. Referents are identified in Q. 44.

[254]Descartes, *Principia Philosophiae*, Q. 39; Descartes, 200. On salt and sweet water, cf. Q. 48 and *Discourses on Meteorology* III and V.

did Burnet, with disastrous consequences for any attempted concordism with the hexameral account).

Within two years after the publication of the *Principia Philosophia*, Descartes abandoned whatever hexameral scheme he may earlier have had in mind.[255] Instead, in the *Conversation with Burman*, Descartes openly asserted that six days were not sufficient for the formation of the Earth. Moreover, in words that echo his remarks to Schurman, Descartes explained that Genesis 1 has nothing to do with natural philosophy, and no correspondence between the two should be looked for by physicists investigating the formation of the world:

> As far as Genesis is concerned, however, the story of the creation to be found there is perhaps metaphorical, and so ought to be left to the theologians. In that case, the creation should not be taken as divided into six days, but the division into days should be taken as intended purely for the sake of our way of conceiving things; this was the way Augustine proceeded when he made the divisions by means of the thoughts of angels. Why, for example, is the darkness said to precede the light?[256]

Regarding the heavens, Descartes now contradicted his earlier statement in the *Principia Philosophiae* that the firmament is the outer edge of the Sun's vortex. Rather, he fell back upon the traditional interpretation that the waters above the firmament are simply clouds:

> With regard to the waters of the flood, they were undoubtedly supernatural and miraculous. The statement about the cataracts of the deep is metaphorical, but the metaphor eludes us. Some say they came down from heaven, and argue that this was where the waters were originally placed at the creation, on the grounds that God is said to have placed the waters above *ha shamayim*. But this word is also very commonly used in Hebrew to denote the air, and I think that it is out of a prejudice of ours that we regard this as 'heaven.' Accordingly, the waters placed above the air are clouds.[257]

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255 "The author could give an adequate explanation of the creation of the world based on his philosophical system, without departing from the description in Genesis.... The author did at one time attempt such an explanation of the creation, but he abandoned the task because he preferred to leave it to the theologians rather than provide the explanation himself." The *Conversation with Burman* was written by Descartes in April 1646.

256 *Conversation with Burman*, 16 April 1648; AT V: 168-169, trans. Cottingham, III: 349-350.

257 *Conversation with Burman*, 16 April 1648; AT V: 168-169, trans. Cottingham, III: 349-350.

It is noteworthy that in this passage Descartes also repudiated any attempt to harmonize his system with the deluge, a fact which buttresses Burnet's claims to originality on this point.[258]

The hexameral forays of natural philosophers such as Descartes and Barin suggest several interesting conclusions. First and most important, attempts to interpret the creation account were regarded as significant by early modern natural philosophers for the development and articulation of theories, even by Descartes up to the time of the writing of the *Principia*. Second, later Cartesian interpreters reveal that a persuasive reconciliation of Cartesian philosophy with the hexameral text remained an important task for the legitimation of Cartesian philosophy through the second half of the century, alongside the outstanding problems of the motion of the Earth and the physics of the Eucharist. A striking sign of the success of this reconciliation is that Leibniz casually referred to Thomas Burnet's Theory in the *Theodicy* (1710), but in doing so Leibniz utterly misinterpreted it, assimilating Burnet's deluge-ruined world within a hexameral framework.[259] Third, from Descartes' apparent study of the hexameral diagrams of Robert Fludd,[260] to his attempts to investigate the Hebrew text, or the accounts by followers like Barin who believed they had succeeded in such reconciliation, lines of inquiry about the formation of the Heavens and Earth were developed with reference to problems framed within the hexameral tradition. These recurring problems included the fluidity of the heav-

[258]Burnet's claim to novelty in his Cartesian interpretation of the Flood is considered on page 624.

[259]Leibniz wrote that because of the revolutions of the primeval globe "we live only on ruins, as among others Thomas Burnet, Chaplain to the late King of Great Britain, aptly observed. Sundry deluges and inundations have left deposits, whereof traces and remains are found which show that the sea was in places that to-day are most remote from it." In this rather Aristotelian expression there is no trace of Burnet's Noah. In the following sentence Leibniz reached a conclusion consistent with his optimistic philosophy of pre-ordained harmony (but diametrically opposed to the sense of ruin which Burnet tried to convey), by suggesting that in spite of appearances of irregularity and disorder in the formation of the Earth, the deluges and other revolutions were those of the first chapter of Genesis: "But these upheavals cease at last, and the globe assumed the shape that we see. Moses hints at these changes in few words: the separation of light from darkness indicates the melting caused by the fire; and the separation of the moist from the dry [presumably, on the third day] marks the effects of inundations. But who does not see that these disorders have served to bring things to the point where they now are, that we owe to them our riches and our comforts, and that through their agency this globe became fit for cultivation by us. These disorders passed into order." *Theodicy*, Part III, paragraph 245; Gottfried Wilhelm Leibniz, *Theodicy: Essays on the Goodness of God, the Freedom of Man and the Origin of Evil*, trans. E. M. Huggard, ed. Austin Farrer (Chicago: Open Court, 1985), 278.

[260]See "Baptizing Descartes," beginning on page 602.

ens, the identity of the firmament and waters above, and the separation of the dry land from the waters below.

§ 9-iv. Cartesian Cosmogonies

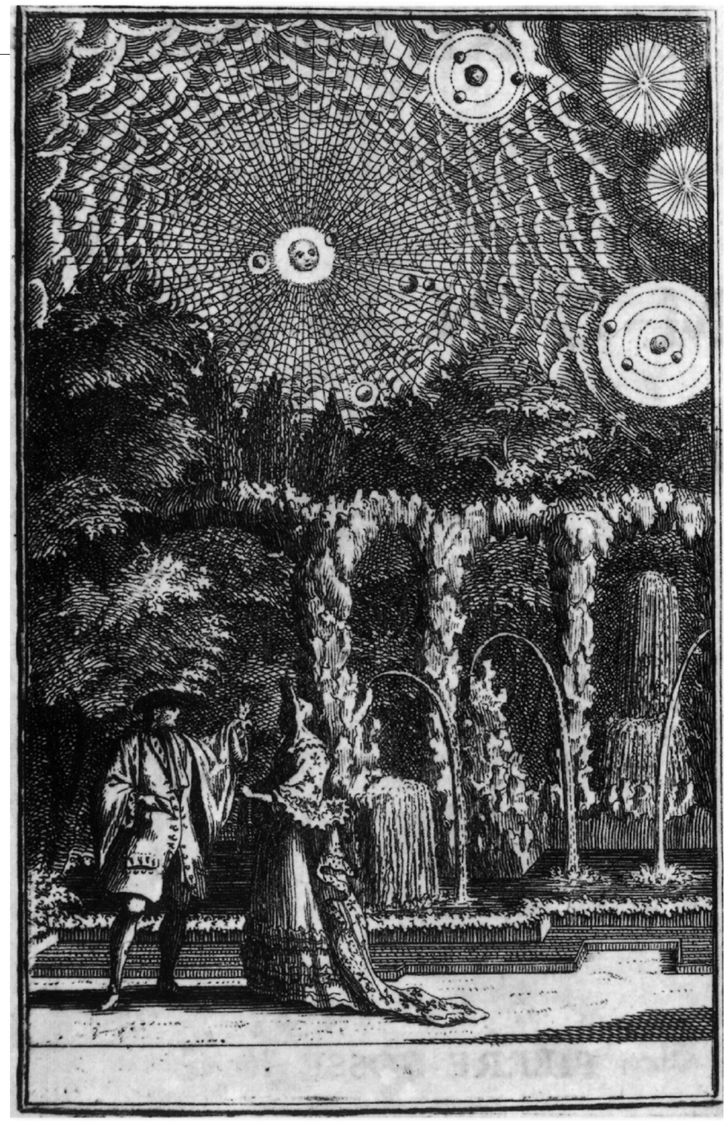


FIGURE 149. Fontenelle, *Plurality of Worlds* (1686), frontispiece. HSCI.

Cartloads of natural philosophers conveyed Cartesian philosophy in the century after the *Principia philosophiae* (1644). For example, a striking Cartesian cosmic section fills the skies behind a landscape scene where Fontenelle discusses the Plurality of Worlds with his female conversationalist (Figure 149).[261]

As hinted in the epigraph to Part I, global views of the Earth as seen from space suggest a close kinship between Theories of the Earth and cosmology in the seventeenth through nineteenth centuries. Not

[261]Bernard le Bovier de Fontenelle, *Entretiens sur la Pluralité des Mondes* (Paris, Lyon: Chez T. Amaulry, 1686).

only were Cartesian themes quite durable; medieval and early modern topics persisted longer than one might expect, animating discussion and stimulating interest through the nineteenth century. For example, Collier relates that Tobias Swinden (1659–1719) was so struck by the depictions of the Sun in Athanasius Kircher's *Mundus subterraneus* that he transfered Hell from the center of the Earth to the center of the Sun (cf. Figure 150).[262]

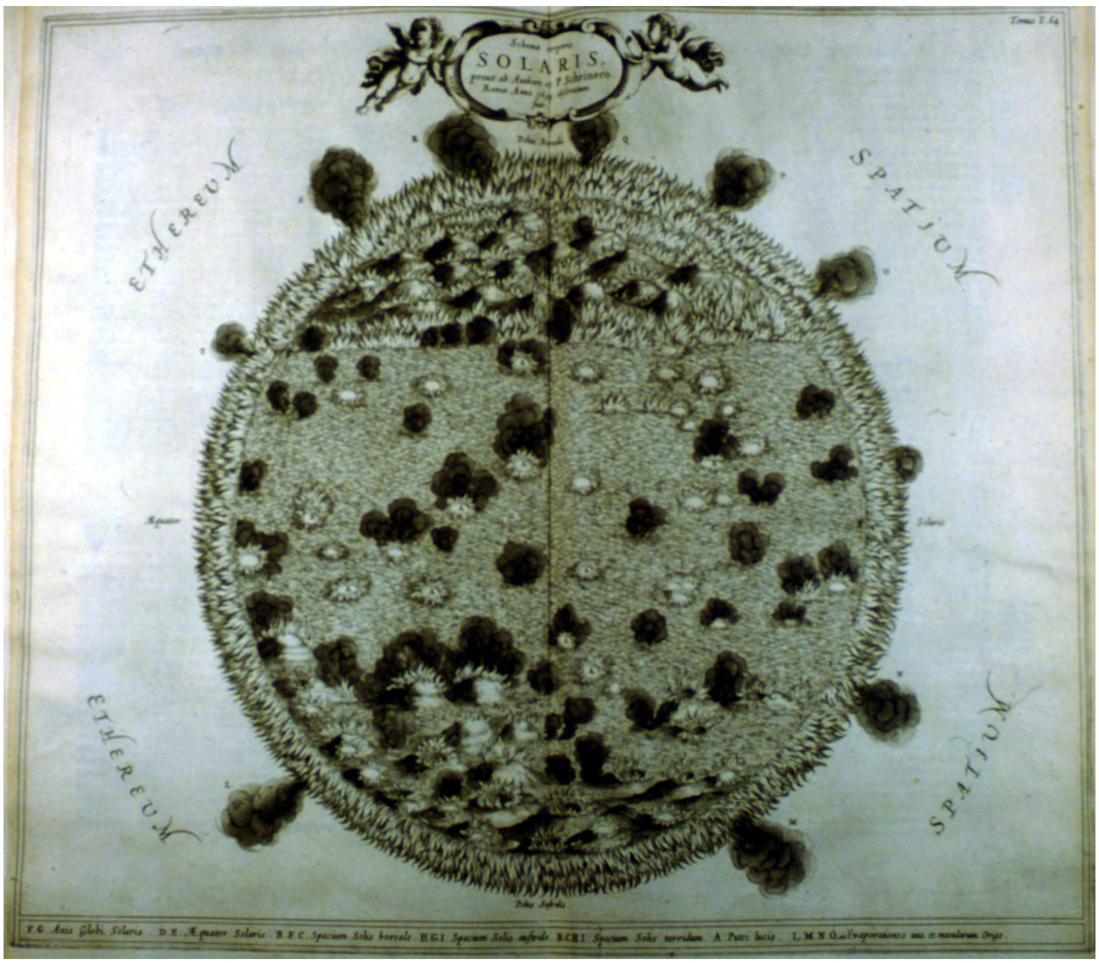


FIGURE 150. Kircher, *Mundus subterraneus* (1664), Solaris. HSCI.

According to the Scandinavian natural philosopher Anders Celsius (1701-1744), in an oration sometimes bound with Linneaus' Theory of the Earth, the Deluge and Conflagration

[262]Tobias Swinden, *Enquiry into the Nature and Place of Hell* (London, 1714). Collier, 61.

show that our planet undergoes changes. Might other planets change in the same ways? Are other planets inhabited, and if so, are they antediluvian, postdiluvian, or in a state of conflagration? Celsius discussed the appearance of Earth from space in its present intermediate state, and then applied his Burnetian Theory of the Earth to other planets, surveying each planet in turn to determine its state, along with the Moon, comets, and fixed stars.[263]

As we have noted for philosophers as diverse as Burnet, Thomas Wright or Thomas Dick, celestial scenery was fraught not only with moral significance, but with physical importance in that the natural processes which shape the Earth might also affect other planets, and analogous features might be discerned on them which would aid in the understanding of our own. Just as Burnet's conception of a paradisiacal globe was corroborated by the banded appearance of Jupiter, so Burnet found cosmic corroborations for his mechanism of crustal collapse. Burnet correlated the tilt in the axes of other planets with their postdiluvian state, and argued that Saturn's ring was an equatorial remnant of an earlier crustal collapse. As we have seen, a defender of Burnet, Thomas Beverley, criticized John Keil for dismissing these suggestions. The Plurality of Worlds literature constituted a textual tradition which paralleled Theories of the Earth and frequently overlapped with it.[264] Celsus cited the same drawings of Jupiter by Cassini as did Burnet (Figure 99 on page 472), and suggested that the blanched appearance of Venus reveals it to be in an intermediate state, but near the conflagration.

[263]Linneaus, *Oratio de Telluris Habitabilis Incremento*. Et Andreae Celsii... *Oratio de Mutationibus Generalioribus quae in superficie corporum coelestium contingunt* (Leiden: Apud Cornelium Haak, 1744).

[264]For Beverley's comments see page 100. On the Plurality of Worlds tradition generally, see especially Steven J. Dick, *Plurality of Worlds: The Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge: Cambridge University Press, 1982), and Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge: Cambridge University Press, 1986).

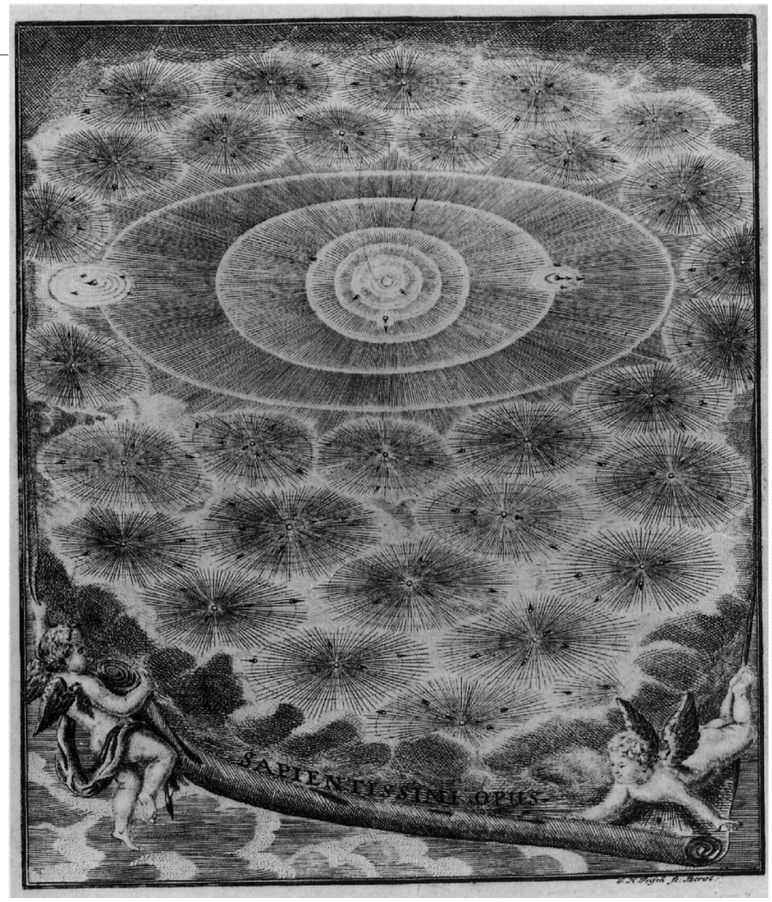


FIGURE 151. Leonard Euler, *Theoria motuum planeterum et cometarum* (1744). HSCI.

Cartesian cosmic sections which substituted helio-concentric cloud-like circles of ether for the crystalline spheres endured into the eighteenth century (Figure 151).[265] Many Cartesians wrote updated versions of the *Principles* to serve as textbooks for university study. Two examples which disseminated Cartesian geogonic diagrams are Claude Gadroys, *Systeme du Monde* (1675) and Nikolaus Hartsoeker, *Principes de Physique* (1706). Gadroys' work includes a version of the Cartesian "wheel of time" (Figure 152), and a hemisphere section (Figure 153).

[265]Leonard Euler, *Theoria motuum planeterum et cometarum* (Berlin: Sumtibus Ambrosii Haude, 1744).

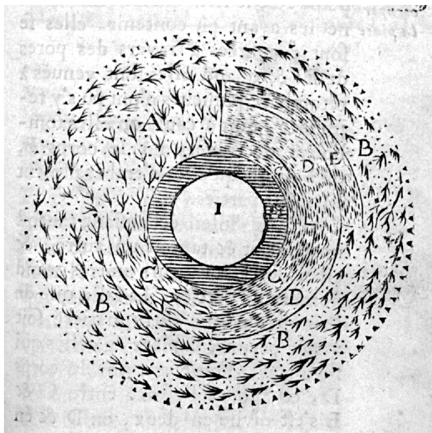


FIGURE 152. Gadroys, *Systeme du Monde* (1675), wheel of time. HSCI.

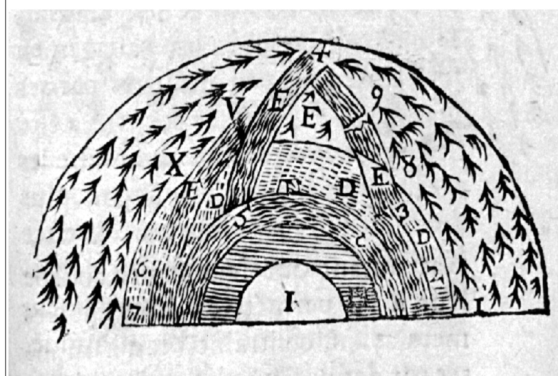


FIGURE 153. Gadroys, *Systeme du Monde* (1675), global hemisection. HSCI.

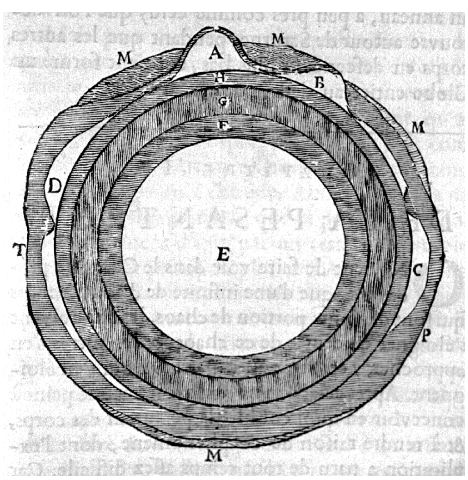


FIGURE 154. Hartsoeker, *Principes de Physique* (1706), 69, 70, 77. HSCI.

Label	Description
E	Central core, formed from the largest and most irregular of the particles
A,B,C,D	Subterranean cavities which underlie different topographical features, such as valleys and mountains
M	Seas
P	Plains
T	Mountainous countries

Hartsoeker's diagram (Figure 154) shows a fiery core (E) overlain by several internal layers (F, G, H). Subterranean cavities (A, B, C, D) underlie different topographical features, including oceans (M), valleys, mountains, islands, and continents. The scheme is confirmed by the occurrence of earthquakes in mountainous countries. Fires occur in the subterranean cavities, and some earthquakes are universal because of the central fire. Hartsoeker cited Plato's account of Atlantis as a reference to an earthquake which caused a crustal collapse that created what is now the Atlantic Ocean; Deucalion's flood likewise resulted from a similar crustal readjustment. Hartsoeker concluded by citing the ring of Saturn as corroboration, which indicated the former extent of that planet prior to collapse of its original crust.[266]

The Cartesian influence was not always as pure as the cases of Barin, Gadroys, and Hartsoeker suggest. The remainder of this chapter will show how these visual conventions were appropriated to serve different contexts.

§ 9-v. Steno's Tuscan Autopsy

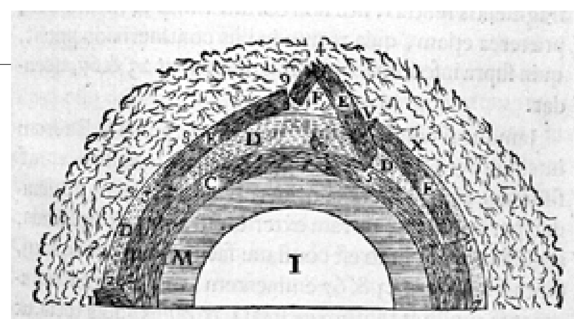


FIGURE 155. Descartes' second hemisection, *Principia philosophiae*, 1644. LHL.

We have seen how Descartes' plates, whether depicting the vortical cosmos or cross-sections of the Earth, represented transformations of bodies over time. Many of these transformations were marked by singular and discrete events as well as gradual and continuous processes. Descartes' second hemisection (Figure 155) contains within itself a number of clues for the reconstruction of a temporal sequence of discrete events. For example, Descartes explained that by analyzing the diagram

[266]Nikolaus Hartsoeker, *Principes de Physique* (Paris: Chez Jean Anisson, 1696), 71–72.

one may deduce that the sunken, depressed 5-end of the 4–5 fragment collapsed earlier than the raised, elevated V-end of the V-6 fragment; that the 6-end fell before the V-end of the same fragment; and that the 3-end of the 3–9 fragment subsided before the 9-end.[267] The sequence of these events is not pictured, but inferred from the final disposition of the structures involved.

Clues for disentangling a chronological sequence of originating events, inherent in the diagram itself, were not emphasized by Burnet. *That* there was a collapse, now evidenced by the *existence* of mountains, mattered a great deal, but the individual *configuration* of the mountains mattered no more to Burnet than the specific sequence of events comprising the crustal collapse. Burnet considered the deluge event as a collective whole, resulting from a single cause (i.e., a crustal collapse) whose multiple effects left a wreck and ruin of entirely accidental (and therefore meaningless) configurations.

> These Mountains are plac'd in no order one with another, that can either respect use or beauty; And if you consider them singly, they do not consist of any proportion of parts that is referrable to any design, or that hath the least footsteps of Art or Counsel. There is nothing in Nature more shapeless and ill-figur'd than an old Rock or a Mountain, and all that variety that is among them, is but the various modes of irregularity; so as you cannot make a better character of them, in short, than to say they are of all forms and figures, except regular. Then if you could go within these Mountains, (for they are generally hollow,) you would find all things more rude, if possible, than without: And lastly, if you look upon an heap of them together, or a Mountainous Country, they are the greatest examples of confusion that we know in Nature; no Tempest or Earthquake puts things into more disorder.[268]

In contrast to Burnet, however, other Theorists made the crustal collapses repetitive and distributed them in a sequence of two or more successive phases often between the creation week and the deluge. To explain their views some employed diagrams designed to facilitate inferences of temporal succession, with or without subsequent (perhaps less general) episodes. The

[267] *Principia Philosophiae* Part IV, questions 42, 44; Descartes, 202, 203.
[268] Burnet, 112–113.

most important such Theorist was Niels Stensen (1638–1686), who published under the Latinized name of Nicolaus Steno.

Steno's tight, carefully-developed argument in the *Prodromus* (1669)[269] culminates in a fourth and final section where he demonstrated the adequacy of his general principles to explain not only specific phenomena such as incrustations, crystals, strata, mountains, and fossils (which he already analyzed), but a particular region of the Earth with its entire assemblage of rock formations, considered as an organized entity in itself. The complexity of the reconstruction required a series of diagrams depicting the manner by which the crust of the Earth was produced. These six diagrams do not correspond to the six days of the creation week, but taken together encompass primeval history from after the deluge back to the beginning of creation (*Prodromus*, *figures 20* through *25;* Figure 156).

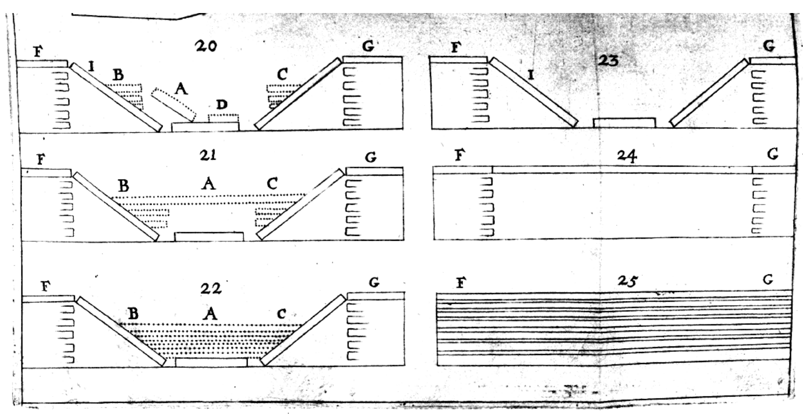
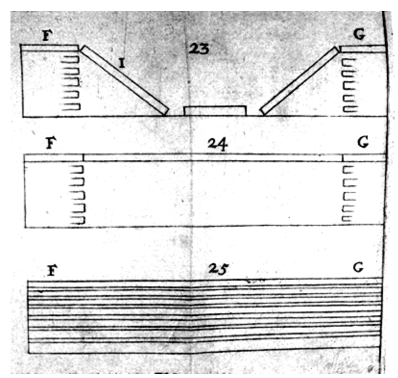


FIGURE 156. Steno's Tuscan sections. *Prodromus*, 1669. HSCI.

Rather than featuring cross-sections of the entire globe like those of Descartes and Burnet, Steno's diagrams model a local vertical section as it might be drawn for the area around Tuscany at six different moments in the past. It should come as no surprise that the particular

[269]Unless otherwise noted, I have used the following edition: Nicolaus Steno, "De solido intra solidum naturaliter contento dissertationis prodromus," in *Steno: Geological Papers*, Latin text with facing English trans. by Alex J. Pollock, ed. Gustav Sherz, 134–235 (Odense: Odense University Press, 1969); hereafter "Steno, *Prodromus*."

region selected for this analysis was Tuscany: the *Prodromus* was dedicated to the Grand Duke Ferdinand II of Tuscany, and was written under the patronage of Ferdinand *in lieu* of a larger dissertation which Steno had promised but did not have time to complete during his Italian residency.[270] The diagrams depict a succession of different structures as if the crust were anatomized by vertical planes of section at six stages in its development.[271] *Figure 20*, the most recent configuration, shows how an observer might have depicted the configuration of the various strata in that locality shortly after the deluge. Solid lines (F or G) represent rocky strata (*strata lapidea*), and dotted lines (A, B, C, or D) sandy strata (*strata arenacea*); the latter sometimes contain fossils.[272] *Figures 21* through *25* model how, by unfolding the clues apparent in *Figure 20*, one may reconstruct the appearance of the site at different times in the past, each figure taking us one step farther back in time.



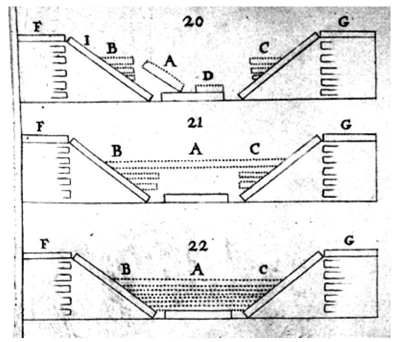
To read the diagrams in the reverse direction, that is, in temporal sequence as a geogonic series from the beginning to the deluge, follow each column from bottom to top and start with the right-hand column.[273] In this way several visual parallels with Descartes' figures emerge. *Figure 25* depicts a smooth, original, rocky crust (shown flat because of the local rather than global scale). The original

[270]Steno, *Prodromus*, p. 139. The Grand Duke was renowned as the sponsor of the Accademia del Cimento, in which Steno participated. One of Steno's major works written for the same Grand Duke two years earlier included an account of his dissection of a shark's head; cf. *Elementorum myologiae specimen seu musculi descriptio geometrica. Cui accedunt Canis Carchariae dissectum caput et Dissectus piscis ex canum genere* (Florentiae, 1667). On the Grand Duke and the Accademia see Michael Segre, *In the Wake of Galileo* (New Brunswick: Rutgers University Press, 1991); Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994); and W. E. Knowles Middleton, *The Experimenters: A Study of the Accademia del Cimento* (Baltimore: Johns Hopkins University Press, 1971).

[271]Steno called these six stages *tempore* or *facies*; i.e., "appearances" at different "times." An anatomist similarly resolves the overall musculature of an organism into distinct facies, or regions distinguishable on the basis of outward inspection. Steno referred to each diagram as a "planum perpendiculare," p. 215. To achieve certainty in anatomical dissections, Steno cautioned that the anatomist should keep a record of every step taken over time and touch nothing without examining it in its natural state: "not only must we be attentive to the part under investigation but we must also reflect on every operation that has preceded this stage and that could have produced some change in the said part." Steno, *Anatomy of the Brain*, 145.

[272]Steno, 215.

crust is layered or "stratified," just like layer E in Descartes' plate (Figure 155 on page 562).[274] In Steno's *Figure 24* the stratum F-G lies above a subterraneous cavity, reminiscent of the way Descartes' crustal layer E stretched across the cavity F. With the collapse of F-G in Steno's *Figure 23* a depressed fragment lies horizontally and an inclined stratum I is formed, much like the seabed 2-3 and inclined fragment 3-9 in Descartes' illustration.



With *Figure 22* a new episode of watery deposition of strata has occurred, as if *Figure 25* were repeated on a more limited scale. The strata deposited at this time are sandy (B-A-C) instead of rocky. *Figure 21* depicts another excavation event. In *Figure 20* there is a second crustal collapse, as the sandy stratum B-A-C fragments into discontinuous strata B and C, inclined stratum A, and depressed stratum D.

Thus both columns represent parallel cycles, each consisting of three stages: layered aqueous deposition, subterranean excavation, and crustal collapse. Since the second cycle repeats the same processes as the first, there is a lateral symmetry between them: the two lower figures model watery deposition of originally horizontal strata, the two middle subterranean excavation, and the two top crustal collapse.[275] Yet the most recent cycle has not oblit-

[273]Although often reprinted in a single column, Steno's six diagrams were originally printed in two columns of three, as Stephen Jay Gould has pointed out in an essay comparing Steno and Burnet; Gould, *Time's Arrow, Time's Cycle*, 55. Gould does not comment on the contrasts analyzed here between Steno and both Burnet and Descartes, nor does he note that the two cycles of Steno's diagrams begin with the creation and deluge, and therefore do not correlate with the two cycles of Burnet's frontispiece where the creation and deluge together comprise the first (descending) cycle.

[274]Layer E is not pictured as stratified in Descartes' diagram, but the text describes a micro-layering of it that occurred over time (see page 554). On the chemical origin of the term "strata" see Kuang-Tai Hsu, "Nicolaus Steno and His Sources: The Legacy of the Medical and Chemical Traditions in His Early Geological Writings" (Ph.D. Dissertation, University of Oklahoma, 1992).

[275]Steno, 205: "Thus, we recognize six different aspects (facies) of Tuscany, two when it was fluid, two when flat and dry, two when it was uneven . . . ." Note in this recapitulation that Steno could read his diagrams chronologically from bottom to top, opposite their numerical order, on occasion (see also his chronological description on pp. 214–215). In Bourguet's terms, note that the first step of each cycle corresponds to Aristotelian Theories, and the second and third stages to Platonic Theories, so it is not surprising that Bourguet classed the *Prodromus* as a mixed Aristotelian and Platonic Theory. See "Louis Bourguet," beginning on page 173.

erated all traces of the former: vestiges of the first cycle of events remain throughout the left-hand figures, from which the natural philosopher may reconstruct the entire linear sequence of changes that has transpired in the Earth's crust. The vestiges or temporal clues present in *Figure 20* include the inclined configurations of strata (from which one infers the collapse of originally horizontal strata), and the discontinuous but laterally corresponding strata (from which one infers their original continuity). A linear history results from recurring cycles of natural processes because the two successive cycles are distinguished by matter and form: the material composition of the strata is either rocky or sandy, by which one infers the era of their original deposition; and the different heights of the horizontal strata may provide corroboratory evidence (some isolated strata from the first cycle remain higher than those formed during the second). The diagrams as a whole provide a remarkable visual model for conceptualizing a directionalist sequence of distinct stages in the development of the crust of the Earth.

The power of these diagrams for reconstructing an irreversible succession of discrete events becomes even more evident if we contrast Steno's work to that of Descartes. The most obvious visual contrast, perhaps, is the regional rather than global extent of the sections. Given this more limited scope some have questioned whether the *Prodromus* even qualifies as a Theory of the Earth, despite incontestable historical evidence that Steno's contemporaries and successors regarded it as a Theory of the Earth.[276] But laying aside external attributions, Steno's work contains nothing that disqualifies it as a Theory of the Earth. The geometrical

[276] To illustrate that Steno was regarded as a Theorist of the Earth one has only to look at the controversy between John Arbuthnot and John Woodward provoked by Arbuthnot's accusations that Woodward extensively plagiarized Steno; cf. John Arbuthnot, *An Examination of Dr. Woodward's Account of the Deluge, &c. With a Comparison between Steno's Philosophy and the Doctor's, in the Case of Marine Bodies dug out of the Earth* (London: Printed for C. Bateman in Paternoster Row, 1697). For a typical example from the continent, the editor of the *Histoire de l'Académie Royale des Sciences* (presumably Fontenelle) spoke of Steno as part of the tradition stemming from Descartes and including Burnet and later writers: "Descartes, car il arrive souvent que l'histoire de quelque recherche, ou de quelque découverte commence par lui, est le premier qui ait eu la pensée d'expliquer mechaniquement la formation de la Terre, ensuite Stenon, Burnet, Woodward, & enfin M. Scheuchzer, ont pris ou étendu ou rectifié ses idées, & ont ajoûté les uns aux autres." This remark occurs at the beginning of a report of an address to the Académie in *Histoire de l'Académie Royale des Sciences* for the year 1708 (Paris: Chez Jean Boudot, Imprimeur Ordinaire du Roy, 1709), 30. Cf. Table 10, "Textual criteria for participation in Theories of the Earth," on page 106.

diagrams were drawn as abstractly as Descartes' or more so, in striking contrast to Steno's strong preference for naturalistic anatomical representations.[277] There are at least three plausible reasons for this departure from established habit: the overlying detrital material and fragments of rock which have accumulated since the deluge have been removed; the diagrams provide a generic scheme applicable to other localities; and their function is to serve as a basis of inference with non-significant details eliminated.[278] Regional investigations of the Earth provide a basis for a global vision if the phenomena observed in the particular locality are taken as typical of or in some manner critical to the structure of the Earth as a whole.[279] Analysis of the region may constitute but the prelude to a synthesis of the globe, a reconstitution of the entire Earth according to the principles obtained from the parts. Such was the case with Steno. As broad as his scope in time, so was his sweep in space. Steno emphasized that

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[277]"We must use every means possible to have exact diagrams, for which a good draughtsman is as necessary as a good anatomist." Steno, *Anatomy of the Brain*, 151. With detailed examples Steno showed that even the anatomical diagrams published by Willis, which he claimed were the most accurate then available, are critically misleading with respect to the pineal gland and the ventricles. Nicolaus Steno, *Discours de Monsievr Stenon svr L'Anatomie du Cerveau a Messievrs de l'Assemblée, qui se fait chez Monsieur Theuenot (Lecture on the Anatomy of the Brain)*, trans. Alexander J. (French) Pollock and Adolf Pilz, Facsimile reprint of the original French edition, Paris, 1669, With English and German translations, Introduction by Gustav Scherz (Copenhagen: Nyt Nordisk Forlag, Arnold Busck, 1965), 135?; hereafter Steno, *Anatomy of the Brain*.

[278]Gabriel Gohau interprets the regional particularity of Steno's diagrams as a chief and fundamental difference between Steno on the one hand and Descartes and Burnet on the other. Gohau seeks to dissociate Steno's work from any tradition of global sections whatsoever, apparently assuming that any regional section is necessarily more realistic than any global section (which allegedly is necessarily more abstract): "It is true that Descartes also illustrated his explanation with plates. However, they were on a global scale, without reference to any real topography. Burnet also included diagrams, but with the exception of the replacement of the central fire by earth, the result was the same as Descartes'. Although book illustrations were rather scarce in the seventeenth century, there were some exceptions in the form of completely abstract diagrams of the globe. For instance, Athanasius Kircher illustrated with several plates his *Mundus subterraneus*, which appeared shortly before the *Prodromus*." Gabriel Gohau, *A History of Geology*, trans. Albert V. Carozzi and Marguerite Carozzi, originally published as *Histoire de la géologie*, revised edition (New Brunswick: Rutgers University Press, 1990), 63. Burnet transformed Descartes' visual representations as he appropriated them, and thus his "results" (despite the fact that he pictured the central fire in some of his sections) were *not* "the same as Descartes'." In this section I claim that Steno creatively appropriated Descartes' vision just as he was indebted to it, not that he developed his views in isolation from it. Contra Gohau, Steno's diagrams are not topographically realistic in contrast to Descartes', but just as geometrically abstract as Descartes' diagrams of crustal collapse (unlike Burnet's diagrams which were drawn freehand, with uneven lines). Inconsistently, Gohau acknowledges on the following page that Steno's "figure 20 is too abstract to give any useful information." The abstraction of Steno's sections in part reflects the fact that they depict the configuration of Tuscany in the near past rather than as an observer would find them in the present. And as we have seen above, Kircher's global sections (like Burnet's global views) were far less abstract than the sections of Descartes and Steno, serving as composites of a host of regional and local illustrations.

[279]See "Roger's Demarcationist Criteria: Global Directionalism," beginning on page 211, and Table 26, "Correspondence of Global and Local illustrations," on page 215.

his analysis was a physics applicable to the entire Earth and not merely a natural history of one particular region: "What I demonstrate about Tuscany by induction from many places examined by me, so I confirm for the whole Earth (*universa terra*) from the descriptions of many places set down by various writers."[280] Steno's conclusions were comprehensively applied. As a global vision, Steno's *Prodromus* cannot be dissociated from the Theory of the Earth tradition, although this has been a temptation for geologist-historians who instinctively distrust the pervasive biblicism of Theories of the Earth while admiring Steno's logical style and emphasis on first-hand geological observation.[281]

The regional rather than global extent of the diagrams served the objectives of Steno's argument. Unlike Descartes, Steno eschewed cosmogony, as well as considerations regarding the ultimate nature of matter not susceptible to ocular demonstration. A limited locality facilitated Steno's precise analytical focus upon more minute phenomena—phenomena which he treated earlier in the *Prodromus* and from which he would synthesize the entire globe. This more precise focus is reflected in his labeling of particular strata (e.g., F-G) rather than physical layers (e.g., Descartes' crust E, which Descartes described as being composed of smaller rind-like divisions). With the initial stage of deposition, Steno depicted the crust as stratified because the subsequent events take place not in a region below the crustal layer (as with Descartes), but in the very area initially occupied by crustal strata. The subterranean cavities are

[280] Steno, *Prodromus*, 204–205. Similarly, what has become known as Steno's principle of lateral continuity asserted that a stratum could cover "the whole globe of the earth" unless interrupted by an older solid body; *Prodromus*, 165. Steno spoke of the *Prodromus* as "*pars Physices*" on p. 189.

[281] For example, Gustav Scherz, the editor of *Steno's Geological Papers,* writes of Steno in an inspirational mode: "The more admirable is his achievement, amounting to genius, since he was in no way inspired or encouraged by intellectual currents of his age, but, became the founder of geological thinking completely on his own, by means of clear, logical thinking and by following up problems which arose out of a comparison of recent living beings with fossils." Steno, 232–233, note 133. I do not by any means dispute that Steno was a genius and an admirable and innovative thinker. Yet, ironically, his logical style (and his formulation of the problem of the place of enclosed bodies) owes much to later forms of scholastic disputation in which Steno was well-educated (as the full title of the *Prodromus* hints), and the painstaking fieldwork and careful observations are deployed in the service of biblicism. Perhaps geologists would find their concerns alleviated to some extent if there were a greater recognition of the heterogeneity of Theories of the Earth as a contested tradition. This heterogeneity relativizes the biblicist aspects by situating contradictory interpretations against one another in support of various rival Theories. The diversity of ways in which biblical interpretations could be deployed in the interpretation of the Earth and in support of competing Theories similarly relativizes appeals to biblical texts by twentieth-century creationists and thereby may relieve some of the anxieties of modern practitioners.

hollowed out not beneath the crust (as with Descartes), but within it. His model of deposition may owe less to Cartesian cosmogony and physics than to the chemistry of sediments and the physiology of fluids.[282]

Additionally, according to Steno's account subterranean excavation might occur as the result of either water or fire, not merely the elevation of vapors from a Cartesian watery abyss. Indeed, Steno did not speculate on the existence of a watery abyss or anything else beneath the outer crust of the Earth. To dispute about unseen interior structures was not required by his account of the crustal strata *per se*. Nor would it have been consistent with his long-practiced habits of anatomical demonstration by means of dissection, where he would begin with the outer surface and take care to make visible whatever was to be demonstrated.[283] Roger French has called attention to William Harvey's anatomical tradition of "ocular demonstration" or *autopsia*, in which an empirical proposition is made undeniably evident to the senses. These terms also justly apply to Steno's habits of disputation.[284]

Like Descartes, Steno argued that to understand a natural object one must understand how it was formed. But in contrast to Descartes, Steno derived his principles from the analysis of the phenomena themselves rather than deducing them from ultimate causes or principles remote from the senses. Beginning by resolving a phenomenon into proximate principles which account for its formation, Steno then generalized those principles and sought to apply them to other analogous phenomena. Finally, with the most general principles in hand, he could employ them to synthesize or reconstruct the most general and complex phenomena.

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[282]See Kuang-Tai Hsu, "Nicolaus Steno and His Sources: The Legacy of the Medical and Chemical Traditions in His Early Geological Writings" (Ph.D. Dissertation, University of Oklahoma, 1992).

[283]Steno was experienced in the art of bringing closure to controversies through the methods of public anatomical dissection even before he came to Italy and deployed these same methods to investigate the origin of fossils in the *glossopetrae* controversy. A letter from Jean Chapelain to the anti-Cartesian Pierre Daniel Huët, 5 April 1665, suggests something of how Steno refuted the Cartesians while he was in Paris: "During the last few months you have missed a lot in the field which interests you so much through your absence from Paris, because M. Stensen, the Dane, has performed the most marvellous experiments ever in this field. He has even forced the obstinate and dogmatic Cartesians to admit the error of their leader with regard to the gland of the brain and its function and this in the presence of the most highly respected people in this city whom he bombarded with the deductions of a calm, reasonable intelligence." Scherz, "Introduction" to Steno, *Anatomy of the Brain*, 70.

This pattern of analysis and synthesis underlies the long continuous argument of the *Prodromus*,[285] although it is often missed by those who regard Steno's conclusions, such as the law of superposition, as geometrically self-evident.[286]

In the *Prodromus* Steno advanced a four-part argument. First he offered what he believed was a novel and true explanation of marine objects found far from the sea, in which he refuted then-popular theories that marine fossils were sports of nature which had grown in the places where they are now found. This specific example clearly showed that to be mistaken about the manner of the temporal production of a natural object would prevent one from understanding the object itself. Temporal processes are paramount.

In the second part Steno addressed the problem by formulating it most generally, *viz.*, "given a substance endowed with a certain shape, and produced according to the laws of nature, to find in the substance itself clues disclosing the place and manner of its production."[287] Steno insisted that the past state and manner of production of a natural thing could be discerned by proper attention to its present state. The natural object still contains within

[284]For example, Steno criticized Descartes with sharp satire, delivered with biting rhetoric in the bodily presence of Cartesians, contrasting Descartes' pretensions about the clarity of nature (at least to him) with Steno's own emphasis on its obscurity. Steno drove home the point that the price of such clarity is to know one's own inventions clearly and completely, though true nature yet remains obscure, even in part: "Regarding the system of M. Descartes—he knew too well the errors in description of the human form to attempt an explanation of its true structure. Thus, he makes no attempt, in his 'Treatise on Man,' other than to explain to us a machine which performs all the function of which men are capable. ...in this sense, it can be said, with reason, that M. Descartes has surpassed other philosophers in this treatise.... No one else has explained all the actions of man mechanically, particularly those of the brain. Others describe for us man himself—M. Descartes speaks to us only of a machine, nevertheless, he lets us see the insufficiency of what others tell us and teaches a way of investigating the uses of other parts of the human body with the same clarity as that with which he shows us the parts of the machine he calls man, as no one has done before him. There is no need, therefore, to condemn Monsieur Descartes if his system of the brain is not wholly in conformity with experience. The excellence of his mind, apparent chiefly in his 'Treatise on Man,' makes amends for the errors in his hypotheses." Steno, *Anatomy of the Brain*, 127–128. Steno then proceeded, in several pages with instructions for careful anatomical dissection, to refute Descartes' description: "I am sure that *eyes alone* are required to observe and recognize a great difference between the machine imagined by M. Descartes and what we see when we study the anatomy of the human body." Steno, *Anatomy of the Brain*, 129. For example, the pineal gland, the seat of the soul in Descartes' mechanistic account of man, is not situated as required by Descartes' theory: "The hypothesis that the arteries are gathered around the gland, rising towards the great *euripus*, is a matter of some consequence in Descartes' system since the separation and motion of the spirits depend on it. Nevertheless, *if you believe your eyes*, you will find only an assembly of veins coming from the *corpus callosum*, from the interior substance of the brain, from the plexus choroides, from various parts of the base of the brain and from the gland itself, you will find that these are veins and not arteries, that they carry blood to the heart whereas arteries carry blood from the heart to the brain." Steno, *Anatomy of the Brain*, 133. Compare the discussion of the demonstrative regress and analysis and synthesis in Chapter 1, "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

itself the clues for reconstructing its mode of formation. The question remains by what general principles one may resolve the present state of a given object into a succession of its past states.

These general principles Steno claimed to identify through resolution of the universal problem ("*resolvitur problema universale*"[288]) according to the laws of analysis ("*analyseos legibus*"[289]). Rather than attributing the failures of previous accounts of the production of natural objects to the lack of any crucial tenet held by some particular school of natural philosophy, Steno refused to commit himself to any particular view of the nature of matter, other than those principles of nature which "are in common use, widely accepted, and are considered admissible by all from every school, whether those who are eager for novelty in

[285]Steno's anatomical disputations followed the same method of analysis and synthesis. Authors who did not begin with analysis, Steno wrote—such as those like Descartes who did not dissect themselves—should be read only for diversion. Steno suggested that their works "would have had much more merit... if they had explained, according to *the laws of analysis*, every method of explaining the actions of animals mechanically ...." Steno, *Anatomy of the Brain*, 143; "les loix de l'Analyse," 40. In Steno's anatomy, analysis refers to making obscure parts apparent to the senses, not merely clear to the intellect: "The first thing to be considered is an account of the parts; in this account, what is true and certain must be determined so that it may be distinguished from false or uncertain propositions. It is not enough either that we clarify each item for ourselves; it is necessary that the evidence of a demonstration should oblige everyone else to agree to it, otherwise the number of controversies will be increased rather than diminished." Steno, *Anatomy of the Brain*, 144. Mere dissection is not adequate without publicly reproducible methods: "Each anatomist engaged in dissection of the brain demonstrates what he has to say about it by experience; the soft tissue of the substance is so pliable that, without due care, the hands mould the parts to suit preconceived ideas. The spectator, seeing often two contrary experiences made on the same part, finds himself puzzled, not knowing what he ought to take as truth, and, in the end, sometimes repudiates both to save himself trouble." Steno, *Anatomy of the Brain*, 144. With respect to the last point, it is interesting to note that Steno's demonstration of the effects of a ligature of the aorta (performed at Thévenot's on 3 March 1665 according to *Anatomy of the Brain*, 68) was unsuccessfully attempted at the Royal Society of London until Steno, when under patronage of the Medicis, forwarded an exact description of his methods; Remacle Rome, "Nicolas Sténon et la Royal Society of London," *Osiris*, 1956, *12*: 244–268, on pp. 254–260.

[286]Kitts provides a helpful clarification: "The justification for [Steno's law of superposition] is not to be sought in its self-evident truth but in a theory of how sedimentary rocks are formed. Steno, in supporting the geological law of superposition, lays the foundation for such a theory. The geological law of superposition is a far from self-evident extension of the everyday law of superposition to a class of geologically-significant entities. If it is to fulfill its critical role in historical inference, moreover, it must contain the assumption that the order of beds in an undisturbed sedimentary section reflects, not only the order in which they were added to the stack, but also the order in which they were formed. The everyday version of the law does not contain this assumption, which again must be justified by pointing to that remarkably complex and theoretical body of knowledge we call sedimentology." David Burlingame Kitts, *The Structure of Geology* (Dallas: SMU Press, 1997), 85.

[287]Steno, *Prodromus*, 141.

[288]Steno, *Prodromus*, 140.

[289]Steno, *Prodromus*, 142.

everything or those who are devoted to the teaching of the past."[290] Steno argued that previous attempts erred in two ways: by failing to identify the various component parts of the general problem, and by failing to distinguish between demonstrated and nondemonstrated principles of nature.[291]

Unlike Galileo or Descartes, Steno did not regard either the Book of God's Works or the Book of God's Word as complete in itself or patently legible in its entirety.[292] For example, Steno cautioned that dissections cannot answer all questions in anatomy. If even descriptive accounts of ventricular anatomy by various persons conflict, much less is there any agreement on the origin of the animal spirits or fluids that might fill them, and still less on the composition of the spirits: "In short, our standard dissections cannot clarify any of these difficulties concerning animal spirit." Long before the *Prodromus*, Steno consistently warned against the failure to distinguish between what can be known and what cannot be known:

> Thus, since anatomical research has not yet reached the degree of perfection that allows for correct dissection of the brain, we should deceive ourselves no further, we should rather acknowledge our ignorance, so that we do not first delude ourselves and then others by promising to show the correct structure.[293]

Steno sought certainty without seeking complete knowledge: "For my part, I prefer to acknowledge my ignorance rather than utter authoritative opinions whose falsehood will be demonstrated by others at some later date."[294] The obscurity of nature, for Steno, undermines attempts to reason teleologically instead of empirically.[295]

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[290]Steno, *Prodromus*, 145. Steno cited the example of Seneca in ethics; Descartes also paid lip service to this trope in the conclusion of the *Principia*. In stark contrast to the epistemic stance of Descartes, however, Steno's posture of learned ignorance is evident from the opening paragraph of his treatise on the anatomy of the brain: "Gentlemen: Instead of promising to satisfy your curiosity concerning the anatomy of the brain, I confess sincerely and publicly here that I know nothing about it. I wish, with all my heart, that I might be the only person to have to speak thus, for I would benefit, in time, from the knowledge of others and it would be a great blessing for the human race if this part of the body, which is the most delicate of all and which is liable to very frequent and very dangerous disorders, were as well understood as many philosophers and anatomists imagine it to be." Steno, *Anatomy of the Brain*, 121.

[291]Steno, *Prodromus*, 143–145.

[292]Cf. page 81 ff.

[293]Steno, *Anatomy of the Brain*, 124–125.

After resolving the general problem of how to account for the place and manner of production of a natural object into several fundamental principles (e.g., that a solid's place of formation can be determined by the impression onto its surface of the contours of the previously-formed solids with which it lies in contact), Steno applied his principles to specific phenomena.[296] By applying to various particular examples the general principles identified in the second part, Steno showed that his principles could successfully account for incrustations, strata of the Earth, crystals, marine shells, and various fossils including the famous *glossopetrae* or shark's teeth previously analyzed by him in *Canis Carchariae dissectum caput* (1667).

Finally, in the climax to the work, Steno applied both the general principles of the second part and the smaller syntheses of the third part—the various particular effects resulting from the general principles operating on a smaller scale—into a global synthesis, featuring the region of Tuscany as representative of the Earth as a whole. Beginning with the present state of the land of Tuscany, Steno resolved it into six different faces as it appeared at six different times from the near-present to the past. Steno introduced this section as follows:

> How the present state of anything discloses the past state of the same thing is made abundantly clear by the example of Tuscany, above all others; obvious inequalities in the present surface contain within themselves clear indications of various changes, which I shall review *in inverse order*, working back from the most recent to the first.[297]

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[294] Steno, *Anatomy of the Brain*, 149. "It is absolutely necessary... to seek for convincing certainty in dissections. I admit readily that it is difficult but I know also that it is not altogether impossible. Do not think, gentlemen, from what I have just said, that I consider that there is nothing certain in anatomy, and that all who practise it shape the parts for us to their own design without being convicted of error...." Steno, *Anatomy of the Brain*, 145.

[295] "Reasonable men must find ridiculous the position of those dogmatic anatomists who, having babbled about the use of parts whose structure they do not know, adduce, on the basis of the uses which they have attributed to them, that God and nature do nothing in vain. But they are mistaken in their application of this general maxim here, and what God, in the temerity of their judgment, destined for a particular end is found, subsequently, to have been made for another. It would be much better, thus, to confess ignorance here, to be more reserved in judgment and not to undertake so lightly the explanation of so difficult a matter on the basis of simple conjectures." Steno, *Anatomy of the Brain*, 150–151.

[296] "I proceed to the more specific examination...." Steno, *Prodromus*, 159.

[297] Steno, 203; italics added.

To employ general principles to infer the past *from the present phenomena* is the inverse of Descartes' causal theory. The more recent phenomena are contingent; not necessary. That is, the phenomena diagrammed in *Figure 20* are not specified *a priori* as the inevitable outcome of a necessary chain of events stretching from Chaos to the contemporary observer. Because the phenomena are contingent in nature, and could have been otherwise, the evidence is artifactual and therefore amenable only to historical reconstruction, i.e., reasoning *from* the effects *to* the causes.

Nevertheless, Steno's Theory is regarded as genetic rather than historical by David Oldroyd:

> But he did not achieve or even contemplate the writing of a complete history of the globe on the basis of his Tuscan investigations. There was no piecing together of discrete pieces of evidence respecting strata in order to build a composite historical account, which would, *qua* history, stand as a means of explaining the Earth's present conditions.[298]

Theories of the Earth are usually critiqued for being too "big"; here Steno is critiqued for thinking too "small." Also, the complexity of the strata (required for a painstaking composite historical account) was far more apparent ca. 1800 than ca. 1700—perhaps in part because the strata were then being taken into account because of the influence of Steno. Oldroyd continues:

> The intentions of Hooke and Steno, then, offered parallels to the aims of the antiquaries, chroniclers and natural historians of the seventeenth century. But Hooke and Steno did not provide examples of Earth histories, except in so far as their accounts intertwined with scriptural or mythological versions of the Earth's past. Hooke had a *theory* of the Earth; but this was not historical in character.[299]

In opposition to Oldroyd's characterization, we will examine in turn Steno's view of mountains and the role of scripture in his vision of the Earth's past.

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[298]Oldroyd, *"Historicism"*, 196.

[299]Oldroyd, *"Historicism"*, 196. Oldroyd's interpretation of Hooke is discussed in "Definitions of Historical Sensibility redivivus: Robert Hooke," beginning on page 354.

The Tuscan diagrams visibly express Steno's explanation of mountains, the majority of which he classified into two species. Original mountains formed at the creation from rocky strata. Frequently they remain horizontally-layered at their summits, but due to subsequently-active mechanisms of elevation and destruction, are not necessarily still the highest mountains. Later mountains formed at the deluge from sandy strata, and are often fossiliferous. Finally, occasional nonstratified mountains comprise a second and altogether different genus of mountains which originated after the deluge from the remnants of the first two types. This nonstratified category consists "of mountains that rise, without order or arrangement, from fragments of strata and from parts that have been worn away."[300] Displaying no visible order or arrangement, it is no surprise that these recent nonstratified mountains were not depicted in the abstract, highly-geometrical Tuscan diagrams. Occurring at the culmination of a scholastic disputation, Steno's taxonomy is as tidy and clear-cut as his geometrical sections. Each of Steno's three kinds of mountains corresponds to a specific time of formation in a meaningful historical sequence (i.e., the creation, deluge, or thereafter). Their observable characters, both material (rocky or sandy) and formal (stratified or nonstratified), allow the time of formation to be inferred.[301]

TABLE 58. Steno's Classification of Mountains

Form	Genus 1: Stratified		Genus 2: Nonstratified
Matter	Species 1: Rocky	Species 2: Sandy	Rocky-Sandy mix
Era	Creation	Deluge	Recent

From the diagrams alone one might infer that Steno's employment of crustal collapse falls short of Descartes' in one critical respect: the elevation of mountains. In Descartes' plate, mountains are elevated higher than the original level of crustal deposition (e.g., 1 and 4 in Figure 155 on page 562). Steno's diagrams do not show how elevation might result from the

[300] Steno, 168–169.

mechanism of crustal collapse; but then they do not necessarily represent the tops of every possible mountain. Given their regional scale one should not hastily infer from the diagram either that Steno did or did not hold to any mechanism for the elevation of the crust above the original level of deposition. In the text, however, he discussed mechanisms of elevation by the mechanisms of subterranean fire and volcanos, and the expansion of subterranean cavities beneath the sea.[302] In contrast to a potential inference from the Tuscan diagrams, the original mountains may not now remain the highest mountains on Earth. Steno verbally rejected this idea because the second cycle (depicted as lower) represented a universal deluge that covered the tops of the original mountains (depicted as higher). Mountain heights change, as they are elevated, eroded, or subjected to collapse:

> It is completely uncertain what the depth of the valleys was at the beginning of the deluge; but reason persuades us that, in the first centuries of the world's existence, cavities were gnawn out by water and by fire, so that slighter collapses of strata followed from this; however, the highest mountains, of which Scripture makes mention, were the highest of the mountains then found, but not the highest of those observed in the present day.[303]

Steno explicitly asserted that "mountains can be destroyed," and at various places alluded to mechanisms of water and wind erosion, subsidence or further collapse, and degradation by

[301] Despite the apparent simplicity of the diagrams, Steno's chronology is easy to confuse: "He accepted that the first period of deposition occurred immediately after the creation, while the collapse of the overlying strata constituted the great flood. He did, however, admit that the later period of collapse represented an episode in the formation of the modern crust that was not mentioned in the Scriptures." Peter J. Bowler, *Norton History of Environmental Sciences*, Norton History of Science, ed. Roy Porter (New York: W. W. Norton and Company, 1993), 116. In another example the confusion is self-contradictory: "He divided geological events into six 'aspects' corresponding to the six days of creation.... He equated the universal deluge with the fourth aspect...." Ellen Tan Drake, *Restless Genius: Robert Hooke and his Earthly Thoughts* (Oxford: Oxford University Press, 1996), 119–120. For Steno, the first and fourth diagrams represent the beginning of the creation week and the beginning of the deluge respectively. The first period of deposition occurred within the creation week and the first collapse either on the third day or after the expulsion from Eden (well before the onset of the deluge). The second crustal collapse occurred as the flood waters receded, although not necessarily immediately. Steno supposed that the postdiluvial formation of the nonstratified, mixed-composition mountains (not shown on the diagrams) was not mentioned in scripture.

[302] Steno, 166–169 and 208–209.

[303] Steno, 206–207.

heat.[304] If the original mountains are not necessarily still the highest, then this accounts as well for the occurrence of fossils on the tops of the highest mountains.

Steno's historical interpretation of mountains was quite different from the perspectives of either Descartes or Burnet. With Descartes, the particular configuration of mountains was not meaningful because it was not causally deduced. The only thing that mattered was the fact that the crust collapsed, not the details of when and where it did so. For Burnet, the collapse was a collective event whose particulars were only accidental and therefore meaningless. But for Steno the events that originated the mountains were neither compressed into a single phase, without a meaningful historical sequence (as with Burnet), nor was the directionalist sequence of those events regarded as insignificant because it was contingent instead of the necessary result of physical laws (as with Descartes' genetic cosmogony).[305]

Contra Oldroyd, the most significant contrast to Descartes apparent from Steno's diagrams is that Steno worked backwards in time, moving from the near-present to the past. Steno pictured what Descartes inferred but did not show: a *reconstructed sequence* of discrete events. Descartes' diagrams represented successive stages of continuous processes which gradually resulted in the deduced layers. His diagram of crustal collapse depicted only the final configuration of the collapse, not the discrete events of the collapse. Steno's diagrams differ by *depicting* a two-cycle, irreversible sequence of discrete events *reconstructed* on the basis of the collapsed configuration, not *predicted* as necessary outcomes of physical causes. There is a

[304]Steno, 169 and *passim*.

[305]Gohau's analysis of Steno is quite perceptive on this point: "Steno thus paved the way for the writing of histories of the earth: that is, the reconstruction of the past based on proofs, or 'monuments' as they were often called in the eighteenth century. These proofs required a certain contingency of history. Indeed, most geological events cannot be forecast because they do not occur according to general laws. Therefore, one cannot do without 'monuments,' or proofs. And this is the work of a historian. A. Cournot has made an excllent distinction between historical investigation and studies based on certain laws and facts: 'The description of phenomena whose stages necessarily follow each other and are linked together according to laws pertaining to reason or experience belongs to the domain of science.' On the contrary, 'many events have occurred in the past which according to their nature cannot be investigated by a theory based on facts or on the knowledge of permanent laws. They can be known only by historical investigation.' After Steno, the earth's past entered into the category of facts that could be investigated historically. The classification of mountains into two groups of different age was to be the first step in that direction." Gohau, 67; citing A. Cournot, *Essai sur les fondements de nos connaissances*, 2d ed (Paris: Hachette, 1912), 460–461. Note that Steno had three groups of mountains, as shown above.

world of difference between causally predicting a collapse and reconstructing the sequence in which various specific events occurred during an undetermined number of collapses. In the former case a crustal collapse is the object of investigation; in the latter critical attention is redirected toward the specific events that together comprise the episodes of collapse, and that redirection of attention is expressed in Steno's depiction of the sequence itself.

By constructing a Theory of the Earth, Steno, like many other theorists, aimed in part to integrate biblical history with the history of the Earth.[306] He announced in the dedicatory letter to the Grand Duke that the *Prodromus* would propose a manner by which a universal deluge could have been produced which was consistent with the laws of nature: "The fourth part... proposes a manner [of production for] a universal deluge that is not repugnant to the laws of natural motions."[307] The effort to provide a naturalistic account of the creation and the deluge was by no means novel or unprecedented. For example, Steno alluded to the well-known Archimedean theory of Jean Buridan and Nicole Oresme that the Earth's center of magnitude (or volume) and center of gravity do not coincide (see "Shifting Centers in early Theories of the Earth," beginning on page 237).[308] Steno refused to be dogmatic in his use of natural knowledge to interpret scripture: "Regarding the manner in which the waters rose, we can put forward various agreements with the laws of nature."[309] Yet his modesty in declining to assert the demonstrated truth of his own view should not be interpreted by the modern reader as evidence that Steno integrated his principles of analysis with biblical history reluc-

[306] In principle, to rely upon sacred testimony as a supplement to the method of analysis and synthesis is no different than to rely upon the testimony of the maker of a machine: "There are two ways only of coming to know a machine: one is that the master who made it should show us its artifice; the other is to dismantle it and examine its most minute parts separately and as a combined unit. Those are the valid methods of learning the contrivance of a machine." Steno, *Anatomy of the Brain*, 139. "Il n'y a que deux voyes, pour paruenir á la connoissance d'vne machine; l'vne, que le maistre qui l'a composée nous en découure l'artifice; l'autre de démonter jusqu'aux moindres ressorts, & les examiner tous séparément, & ensemble." Steno, *Anatomy of the Brain*, 32.

[307] "Qvarta pars... modumqve diluvii universalis proponit, motuum naturalium legibus non repugnantem." Steno, *Prodromus*, 140–141.

[308] Steno, *Prodromus*, 204–207. Steno returned to pass favorable comments on these mechanisms in his conclusion.

[309] Steno, *Prodromus*, 205.

tantly or without conviction, almost as if this final section were an afterthought. Nor can the discussion of biblical history in the final section be dismissed as a superfluous part of Steno's argument. To do so would be to ignore a repeated pattern of analysis and synthesis that climaxes here in the fourth section with what rather constitutes his final application of broadest scope. Given Steno's desire to please his patron, the rhetorical value of the prominence of Tuscany depended upon the culminating significance of this section in the logical structure of the work. Moreover, Steno's proposal for the manner of production of the deluge precisely reflects the aims of the central problem he was attempting to solve at various levels of generality in the *Prodromus*, formulated just a few lines earlier in the same dedication: "Given a substance endowed with a certain shape, and produced according to the laws of nature, to find in the substance itself clues disclosing the place and manner of its production."[310] In the fourth section, the "substance endowed with a certain shape and produced according to the laws of nature" is the crust of the Earth, and the correlation of his Theory with events known from biblical history, particularly the creation and the deluge, served authoritatively to corroborate the entire work.

In several places throughout the *Prodromus* Steno had his eye on the possible application of his views to the traditional inquiry into natural mechanisms to account for the creation and deluge.[311] For example, at the end of the first third of the *Prodromus* where Steno began a discussion of the material composition of various strata, the first proposition is: "If all particles in

[310]"Dato corpore certa figura praedito, et juxta leges Naturae producto, in ipso corpore argumenta invenire, locum et modum productionis detegentia." Steno, *Prodromus*, 140–141.

[311]This is consistent with Steno's use of data from the scriptures in other writings, such as the physiology of tears and the meaning of gems. For example: "But as regards the circumstance that tears of blood have been observed to accompany very great sorrow, this supports our opinion considerably; for if the veins, in case they were not made narrower than the arteries, allowed free passage to the blood, the latter of itself would never pass out through the fine channels which are adapted solely to the serous components. Therefore, backward flow into the veins being inhibited, the blood must either have dilated the channels intended for the secretion of serum or burst them and in that manner created a channel which it followed until it could freely re-enter its usual channels after the directing of the Spiritus animales into the said parts had ceased." Steno, *Anatomical Observations of the Glands of the Eye and their New Vessels thereby revealing the true source of tears (Observationes Anatomicae, quibus Varia Oris, Oculorum, & Narium Vasa describuntur, novique salivae, lacrymarum & muci fontes deteguntur, et Novum Nobilissimi Bilsii De lymphae motu & usu commentum Examinatur & rejicitur; 1662)*, trans. W. E. Calvert, facsimile reprint, With a Preface and Notes by Edv. Gotfredsen (Copenhagen: Nyt Nordisk Forlag, Arnold Busck, 1951), 20.

a stony stratum are observed to be of the same nature and of fine size, it cannot reasonably be denied that this stratum was produced at the time of Creation from a fluid that then covered all things; Descartes, too, accounts for the origin of the Earth in this way."[312] This proposition about the homogenous material of the original strata is deployed, in conjunction with propositions about the figure or outline of strata, to establish the earliest of the six *facies* in the analysis of Tuscany:

> With regard to the first face of the Earth, Scripture and Nature agree in this respect, that everything was covered with water; but of how and when it began, and how long it lasted as such, Nature says nothing while Scripture speaks. That there was aqueous fluid, however, at a time when animals and plants had not yet appeared, and that the fluid covered everything, is proved conclusively (*evincunt*) by the strata of the higher mountains (*montium altiorum*) which are free from all heterogenous material; the outline (*figura*) of these strata testifies to the presence of a fluid; their material bears witness to the absence of heterogenous bodies; the similarity in materials and outlines (*figurae*) of strata from different mountains that are widely separated (*invicem remotorum*) proves indeed that the fluid was universal.[313]

Even the famed principle of lateral continuity, when applied to the original strata, is deployed in Steno's analysis for the purpose of establishing the universality of the watery chaos early in the creation week.

The concordism between Steno's six stages and biblical history is summarized in Table 59. Consider how Steno introduced the concordance between his geological views and biblical histories, with phrases such as "Scripture and Nature agree..." or "Nature says nothing, while Scripture speaks." There are other examples where "neither Scripture nor Nature determines." Where the meaning of scripture even as interpreted by the Church is obscure, novel views explicated in agreement with Nature may safely be entertained: "But lest anyone

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[312]Steno, *Prodromus*, 162–163. This is the only explicit mention of Descartes in the *Prodromus*. Note that Steno did not cite Descartes on this point because he expected that Descartes would constitute an acknowledged and unproblematic authority for Steno's readership. Rather, the comment makes the rhetorical point that if even Descartes could not doubt it then the proposition represents an indubitable consensus among different sects.

[313]Steno, *Prodromus*, 204–205. Cf. earlier discussion of mountains for Steno's usage of strata, fluid, figure, and lateral continuity.

be afraid of the danger of novelty, I set down briefly the agreement (*consensum*) between Nature and Scripture, reviewing the main difficulties that can be raised about individual *facies* of the earth."[314] For Steno, strata became historical artifacts from which the past could be reconstructed exactly as one would use historical information from scripture or from reliable historical records:

> That there was aqueous fluid, however, at a time when animals and plants had not yet appeared, and that the fluid covered everything, is proved conclusively [*evincunt*] by the strata...[315]

While not everything may be known, when scripture and nature speak with a clear and united voice one may claim certain knowledge of the Earth's past.

TABLE 59. The Two Books: Steno's Concordism

Fig	Condition	Scripture	Nature	History	Verdict[a]
25	Fluid	Clear for when and how (creation)	Silent for when and how, but clear that it did so	Silent	"of how and when it began, and how long it lasted as such, Nature says nothing, while Scripture speaks." "Scripture and Nature agree in this respect, that everything was covered with water; ..." (205)
24	Flat and dry	Clear for when and how (Eden[b])	Silent for when and how, but clear that it did so	Silent	"When and how the second aspect of the earth, which was flat and dry, began, Nature is silent, while Scripture speaks; moreover, Nature's assertion that such an aspect of the earth did exist at one time is confirmed by Scripture when it teaches that waters gushing from one source overspread the whole earth." (205)

[314]Steno, *Prodromus*, 205.
[315]Steno, *Prodromus*, 204–205.

TABLE 59. **The Two Books: Steno's Concordism**

Fig	Condition	Scripture	Nature	History	Verdict[a]
23	Uneven	Silent for when, Clear that (before the deluge)	Silent for when, Clear that	Silent	"When the third aspect of the earth... began, neither Scripture nor Nature determines; Nature shows that the unevenness was of some magnitude; Scripture, moreover, mentions mountains at the deluge" (205–207)
22	Fluid	Clear (deluge)	Clear	Agrees	"The production of hills from marine deposits testifies that the sea was higher than it is now, and this not only in Tuscany but also in very many places far enough from the sea... Nature does not contradict what Scripture determines about how high the sea was...." "With regard to the time of the universal deluge, sacred History... is not opposed by secular history...." (207)
21	Flat and dry	Silent (after the deluge)	Clear	Not clear	"Nature demonstrates the existence of those plains while Scripture does not contradict their existence; moreover, nothing can be determined about whether the sea receded completely and immediately, or whether indeed, in the course of centuries, new chasms opened to provide an opportunity for the discovery of new regions, since Scripture is silent, and the history of nations regarding the first ages after the deluge is regarded as doubtful by the nations themselves..." (209)
20	Uneven	Silent	Clear	Not clear	"The sixth aspect is obvious to the senses..." "The history of the first centuries after the deluge is confused and doubtful among secular writers..." (211)

a. Page numbers from Steno, Prodromus, follow each quotation.
b. Cf. Genesis 2:6, "But a mist went up from the earth and watered the whole face of the ground."

§ 9-vi. A Newtonian Cosmogony: Whiston's Hexameral Theory

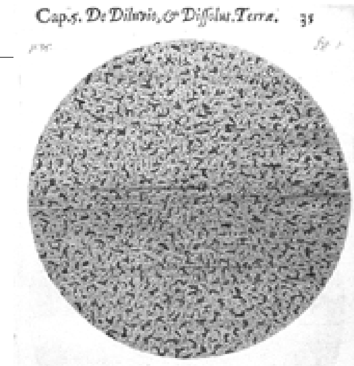


FIGURE 157. Burnet's *Figure 1*, Chaos. HSCI.

Descartes and Burnet established a repertoire of diagrams and a variety of visual conventions for mapping transformations in the Earth and its crust over time. Burnet's diagrams so powerfully conveyed his Theory of the Earth that when William Whiston attacked Burnet and offered his own *New Theory of the Earth* (1696), the global sections he used were copied almost directly from Burnet.[316] Burnet's *Figure 1* represented the Chaos (Figure 157), and for Whiston this Chaos was a comet. Whiston wrote that a comet consisted of "a Central, Solid, Hot Body, of about 7000 or 8000 Miles in Diameter," surrounded by a rarefied heterogenous atmosphere about 100,000 miles in diameter. To depict this comet-chaos, Whiston explained: "the Theorist's First Figure, excepting the omission of the Central Solid, will well enough represent it."[317]

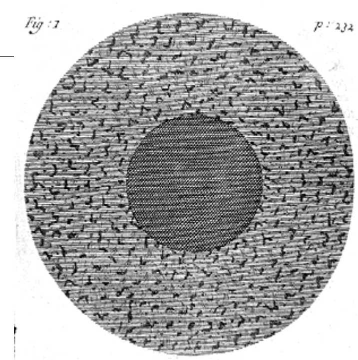


FIGURE 158. Whiston's first geogonic section. (Before day 1.)

Whiston's *Figure 1* (Figure 158) is an almost identical redrawing of Burnet's *Figure 1*, except for the solid hot core added in the center region. This core identifies the Chaos as a cometary body.

[316]William Whiston, *A New Theory of the Earth, from its Original, to the Consummation of all Things. Wherein The Creation of the World in Six Days, The Universal deluge, And the General Conflagration, As laid down in the Holy Scriptures, Are shewn to be perfectly agreeable to REASON and PHILOSOPHY. With a large Introductory Discourse concerning the Genuine Nature, Stile, and Extent of the Mosaick History of the CREATION* (London: Printed by R. Roberts, for Benj. Tooke, 1696); hereafter simply "Whiston."

[317]Whiston, 231.

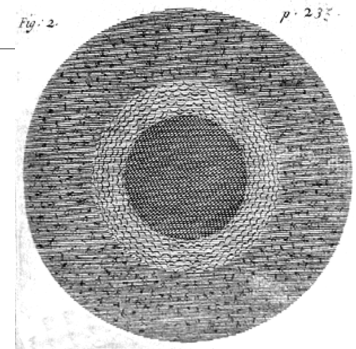


FIGURE 159. Whiston's second geogonic section. (Before day 1.)

Whiston appropriated Burnet's *Figures 2* through *4* in almost identical form.[318] In text accompanying *Figure 2* (Figure 159; compare with Burnet, Figure 87 on page 458), Whiston described a division of the outer atmosphere according to specific gravity. This separation yielded a dense and heavy Abyss that encompassed the central solid Body, and an outer, more airy region composed of a mixture of particles. So far, Whiston's account and diagram resemble Burnet's.

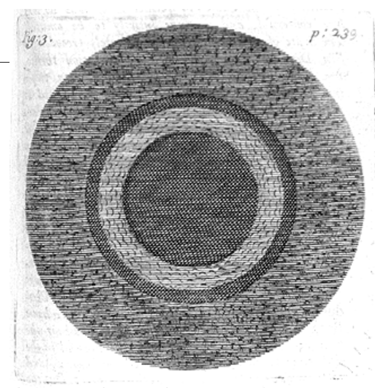


FIGURE 160. Whiston's third geogonic section. (Day 1.)

With *Figure 3* (Figure 160; compare with Burnet, Figure 90 on page 460) Whiston described the formation upon the Abyss of a "Solid Orb of Earth," just as did Burnet. Finally, in *Figure 4* (Figure 161; compare with Burnet, Figure 91 on page 460) the outer airy region surrounds the

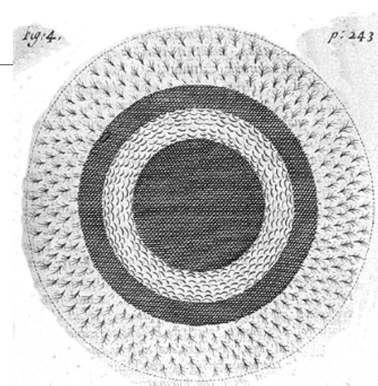


FIGURE 161. Whiston's fourth geogonic section. (Days 2 and 3.)

thick crust of the Earth, which in turn contains the subterranean waters, in correlation with Burnet's use of the same diagram.

[318]Whiston, 235–243. Whiston's diagrams have been redrawn, modeled very closely upon Burnet's originals—so much so that Whiston explicitly refered to the diagrams as Burnet's.

Yet this durability of visual representation belies the quite different contexts, both cosmological and theological, into which Whiston appropriated them. To Whiston, Newton rather than Descartes read the book of God's Works aright, and Moses rather than Peter wrote the relevant passages of God's Word.

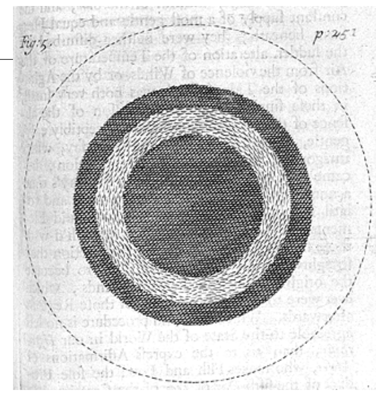


FIGURE 162. Whiston's fifth geogonic section. (Day 4.)

Whiston's *Figure 5* (Figure 162; compare with Burnet, Figure 92 on page 461) does not parallel Burnet's use of the same figure, for Whiston appropriated it into the context of the creation week to represent the work of the fourth day.

Both Burnet and Whiston emphasized that scripture cannot be interpreted rightly, or literally, without the aid of a good physical theory. But unlike Burnet, Whiston set out to find a concordism between the Hexameron and the stages in the formation of the present state of the globe. Whiston's Theory began with a 94-page "Discourse Concerning the Nature, Stile, and Extent of the Mosaick History of the Creation." For Whiston it was imperative to specify how these didactic diagrams of the formation of the Earth fit into Moses' account of the creation week.

All along Whiston's use of the Burnetian global sections served a hexameral chronology. For Whiston, the first two sections preceded the works of the six days, when darkness covered the face of the deep (the chaotic cometary atmosphere) and the Spirit hovered over the waters.[319] During the first day, represented by *Figure 3* (Figure 160), the nonfossiliferous strata were laid down and the crust hardened over the enclosed abyss. At some point either prior to or at the beginning of the first day, the cometary chaos was given an annual motion in a circular orbit around the Sun, either by the direct finger of God or by some other peculiar

[319]Whiston, 234.

providence.[320] The outer atmosphere began to clear, allowing light from the Sun to pass through, which successively illuminated the entire globe.[321] According to the traditional hermeneutical principle of accommodation, Whiston argued that "Let there be light" and similar phrases could be interpreted with respect to what an observer of the visible world would perceive if watching from the standpoint of the surface of the Earth itself.[322]

Whiston used the fourth figure (Figure 161) to illustrate the works of the second day, the separation of waters above and below a firmament. Consistent with typical Protestant interpretations, Whiston identified the firmament as the air and the superior waters as the vapors in the clouds. These vapors escaped being trapped beneath the outer layer of crust in the subterranean watery abyss.[323] To this point there is little in Whiston's account that would necessarily contradict Burnet's chronology.

With his account of the third day, using the same figure (Figure 161), Whiston irrevocably parted company with Burnet. For Whiston there must have been a separation of dry land and sea rather than a smooth and uniform Paradisiacal globe. Consequently, Whiston argued that the settling of particles out of the chaos did not produce a uniform crust, or Orb of Earth, but that it consolidated unevenly and compacted irregularly: "by reason of its Columns, different Density, and Specifick Gravity . . . it was setled into the Abyss in different degrees, and thereby became of an unequal surface distinguish'd into Mountains, Plains and Valleys."[324] Original strata, contra Steno, were not horizontal or concentric but irregular and inclined. This did not require mountains as high or oceans as vast as presently occur on the Earth, but it did allow for the emergence of dry land above lesser seas. Whiston appropriated

[320]This occurred just after the cometary chaos had passed its perihelion, so that it had acquired a "prodigious Heat" from the Sun sufficient to keep its core warm for thousands of years. Cf. Whiston, 258.

[321]Whiston, 236.

[322]Whiston, 239–240.

[323]Whiston, 241–244.

[324]Whiston, 245.

the fourth section to illustrate the hexameron to this point because of the insensible vertical thickness of the surface implied by diagrams drawn to a small scale: "And if we allow for the defect of the inequalities of the outward Surface, too small to be therein consider'd; and suppose the Atmosphere somewhat clearer than before; the former figure will still serve well enough, and represent the progress and state of the Earth at the conclusion of this Third Day."[325] Needless to say, Burnet would have found the uneven paradisiacal surface postulated by Whiston as repugnant as Whiston's use of his beautifully smooth diagrams to illustrate it.

Throughout the creation week, according to Whiston, the Earth had an annual motion but no daily or diurnal motion. Consequently, each day was equivalent to a year; its "evening and morning" were six months of darkness followed by six months of daylight. This "literal interpretation" of the length of the days resolved a number of exegetical difficulties for Whiston.[326] For example:

> Two such Works are by Moses ascrib'd to the third Day, which (if that were not longer than one of ours now) are inconceiveable and incompatible. On the former part of this Day the Waters of the Globe were to be drain'd off all the dry Lands into the Seas; and on the same Day afterward, all the Plants and Vegetables were to spring out of the Earth. Now the Velocity of running Waters is not so great, as in a part of one of our short Days, to descend from the middle Regions of the dry Land into the Seas adjoyning to them;....[327]

Thus on the third day, during six months of darkness, vapors condensed and fell upon the Earth, filling its depressions to form the seas. During the subsequent six months of daylight, the newly-watered and fertile land sprouted the terrestrial plants, as Genesis related.[328]

As a consequence of the accommodation of the hexameral account to an earthbound perspective, the Sun and stars, though created before the creation week, were not described until

[325] Whiston, 247.
[326] Whiston affirmed that it was a "literal" interpretation on p. 247.
[327] Whiston, 89.
[328] Whiston, 244–248.

the fourth day when the atmosphere cleared enough to make them distinctly visible. This state could be represented by *Figure 5* (Figure 162; compare with Burnet, Figure 92).[329] Burnet's sixth figure illustrated the oval shape of the globe, which Whiston incorporated into a diagram pertaining to the deluge, discussed below. Whiston provided no diagram to illustrate the work of the fifth day, i.e., the production of aquatic and aerial life.

The year-long "days" assisted Whiston in his explanation of the sixth day as well. The production of the terrestrial animals occurred during the first half of the sixth year. Created in the morning of the sixth day, that is, at the beginning of the second half of the sixth year, Adam enjoyed perhaps six months in Paradise before his Fall (which Whiston situated at the beginning of the seventh day[330]). Besides giving Adam time to name the animals before falling into the deep sleep during which Eve would be formed from his rib, a long day allowed for their mutual acquaintance and joint appointment as stewards of the Earth.[331]

In contrast to Burnet, for Whiston the Fall was a more catastrophic event for the Earth than the deluge. The contrast between Adam's moral state before Paradise and after the expulsion was far greater than the moral contrast before and after the deluge. Commensurate with this, since "Almighty God adapts each particular [natural] State to such rational and animal Beings as are on purpose designed for the same," the Fall must have been the occasion of a greater change in the state of nature than the deluge.[332] For this reason Whiston claimed that his was "the *first* attempt at an *Intire Theory*, or such an one as takes in *All* the great Mutations

[329]Whiston, 248–251.

[330]Whiston, 257.

[331]Whiston, 81–91.

[332]Whiston, 101. A similar conclusion was argued quite strenuously by Francis Bacon: "heaven and earth which were made for man's use were subdued to corruption by his fall." Vickers comments on this passage that not only did Bacon take the creation account literally, but he developed "in an equally literal way, the implications for natural philosophy of the Fall, in particular its effects on the laws of nature." Brian Vickers, ed., *Francis Bacon: A Critical Edition of the Major Works*, The Oxford Authors, ed. Frank Kermode (Oxford: Oxford University Press, 1996), 109, 565. Steno recognized the nonspecificity of scripture with his studied ambiguity on the timing of the first crustal collapse, perhaps in order to accommodate an alteration of the Earth at the Fall as well as on the third day.

of the Earth."[333] At the Fall the Earth was given a shock, either by the direct finger of God or by the passing of a comet in God's particular providence,[334] which commenced its diurnal motion around an axis inclined to the axis of its previously-established annual revolution around the Sun. As a result the length of a day was shortened from one year to 24 hours. Given the obliquity of the ecliptic, the Paradisiacal state of perpetual equinox was destroyed and replaced by tropical zones. Most significantly, perhaps, due to its rotation the Earth changed its figure from perfectly spherical to an oblate spheroid, bulging at the equator due to centrifugal forces. This stress produced cracks and fissures in the outer crust, much as John Woodward had argued in his Theory of the Earth.[335] Whiston provided a *Scholium* summarizing the effects of the Fall, suggesting that volcanos arose as they were fed by the fissures in the crust, and that tides became more frequent and severe as the rotational movement compounded the annual.[336]

[333]Whiston, 102–103.

[334]Whiston, 223.

[335]Whiston, 260: "If therefore Dr. Woodward be right in asserting, That the Cracks and Fissures, which he calls perpendicular ones, since the intire Consolidation of the Strata of the Earth, are necessary to the Origin of Springs, (and I believe he may have good grounds for his Opinion) from the Being of such Springs and Fountains after the Consolidation of the Strata, and before the Flood, 'tis evident, that the Diurnal Motion did not commence till after the Annual; nay, till after the Formation and Consolidation of the Earth...."

[336]Whiston, 277–279. Cf. Galileo's "Discourse on the Tides" (1616) in Maurice A. Finocchiaro, *The Galileo Affair: A Documentary History* (Berkeley: University of California Press, 1989).

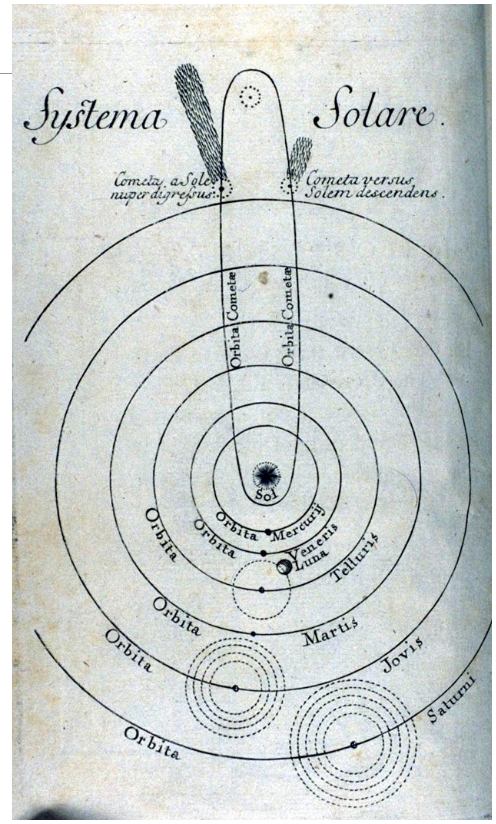


FIGURE 163. Whiston's *Systema Solare*. Frontispiece.

It was not merely his hexameral orientation that set Whiston and Burnet apart, however. Whiston's Newtonianism is as evident in his illustrations as his hexameral orientation. His frontispiece, and the seven figures prominently displayed at the front of his Theory, all feature comets in an unmistakably Newtonian perspective.[337] The frontispiece depicts a comet in a closed orbit, descending toward the Sun with a growing tail on the right, and ascending away from the Sun, tail enlarged, on the left (Figure 163). The reduction of cometary motions to the mathematical rule of an elliptical orbit symbolized the triumph of Newtonian mechanics over Cartesian cosmology (and was here followed by a Latin dedication of the entire work to Newton). Whiston frequently argued that the new view of comets was incompatible with Cartesian vortices. Whirlpools of matter would disrupt or interfere with comets' periodic and closed but noncircular orbits; their highly variable inclinations to the ecliptic; their frequently retrograde orbital directions; and their rarefied and transparent tails of great length.[338]

[337]On the significance of comets according to Newton, Whiston and Halley cf. David Charles Kubrin, "Newton and the Cyclical Cosmos," *Journal of the History of Ideas*, 1967, 28: 325–346; Simon Schaffer, "Newton's Comets and the Transformation of Astrology," in *Astrology, Science and Society: Historical Essays*, ed. Patrick Curry, 219–243 (Wolfeboro, New Hampshire: Boydell Press, 1987); Sara Schechner Genuth, "Comets, Teleology and the Relationship of Chemistry to Cosmology in Newton's Thought," *Annali dell'Istituto e Museo di Storia della Scienza di Firenze*, 1985, 10: 31–65; and M. A. Hoskin, "The English Background to the Cosmology of Wright and Herschel," in *Cosmology, History and Theology*, ed. W. Yourgrau and A. Breck, 219–232 (New York: Plenum Press, 1977).

[338]See for example, Whiston, 36.

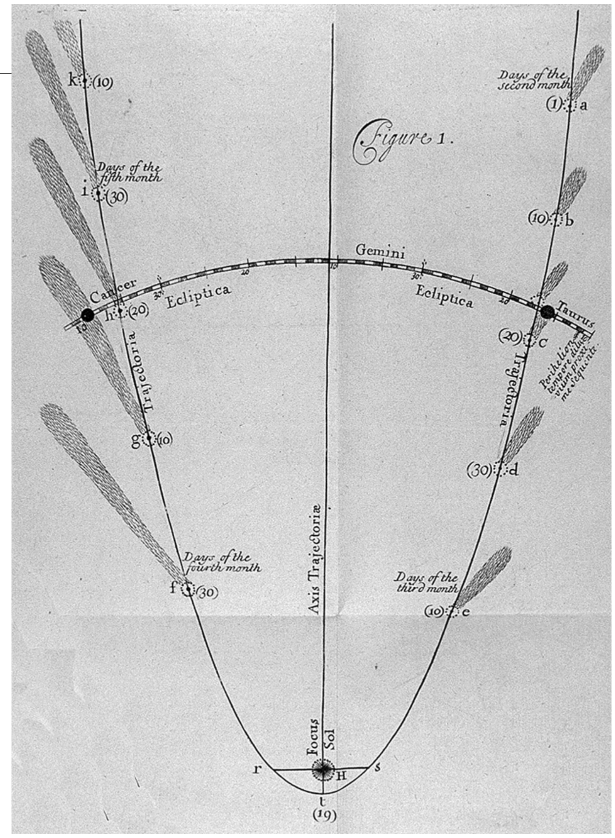


FIGURE 164. Whiston, *Figure 1*. Cometary deluge.

In Whiston's *New Theory of the Earth* the favored Newtonian agent, comets, arrived in time for almost every purpose under heaven: for providing the material of the Chaos at creation, for giving the Earth a shock at the Fall, for supplying the water of the Noachian deluge, and for burning the Earth at the final conflagration (Table 60). We have seen how the creation of the Earth commenced with a cometary chaos. At this point we need only consider his account of the deluge. From the perspective of deep space, *Figure 1* (Figure 164) depicts the varying lengths of a comet's tail. The comet is depicted at respective positions during its approach and retreat from the Sun, starting with the first day of the second month continuing to the tenth day of the fifth month. These dates synchronize with the Mosaic account of the deluge, which began on the "seventeenth day of the second month" when the "fountaines of the great deepe were broken up, and the windowes of heaven were opened" (Genesis 7: 11).[339]

[339] See Whiston, Hypothesis IX: "The Deluge began on the 17th Day of the second Month from the Autumnal Equinox, (or on the 27th Day of November in the Julian Stile extended backward) in the 2365th year of the Julian Period, and in the 2349th year before the Christian Aera"; 123–126. Whiston here followed Usher's chronology, although he altered it in various ways when he later translated Josephus' *Antiquities*. After the "rain was upon the Earth forty days and forty nights" (Genesis 7: 12) the waters "prevailed upon the Earth, an hundred and fifty days" (Genesis 7: 24) before abating. With the windows of heaven closed and the fountains of the deep stopped up, the Ark came to rest upon the mountains of Ararat "in the seventh month, on the seventeenth day of the month" (Genesis 8: 4). Thus five months of 30 days transpired between the onset of the deluge and the landing upon Ararat, from the second to the seventh months. Hypothesis X discussed the cometary mechanism of the Deluge: "A Comet, descending, in the Plain of the Ecliptick, towards its Perihelion; on the first Day of the Deluge past just before the Body of our Earth"; 126–156. Whiston's Deluge theory is contained in these two Hypotheses, which are explicated further in Book IV, *Solutions*, chap. IV, pp. 300–367.

TABLE 60. Effects of Past Cometary Impacts, Whiston (1696)

Event	Cometary effects
Creation	•Earth's watery chaos, from which proceeded the events of the creation week, derived from a comet (no impact; it moved into a regular annual motion; 1 day = 1 year; Edenic conditions of perpetual equinox prevailed)
Fall	•Shock of impact produced daily motion; days shortened to 24 hours •Rotational axis inclined to the Sun •Eden replaced by tropical zones as seasons began •Earth became an oblate spheroid from stress of rotation; created fissures in outer crust
Deluge	•The watery head of an approaching comet provided the "windows of heaven," source of deluge waters •Gravitational tidal forces shattered already cracked crust of Earth, releasing the "fountains of the deep" •Orbit of Earth altered from circular form to an ellipse, increasing the length of a year by 10 days
Conflagration	•A fiery comet receding from the Sun will engulf the Earth

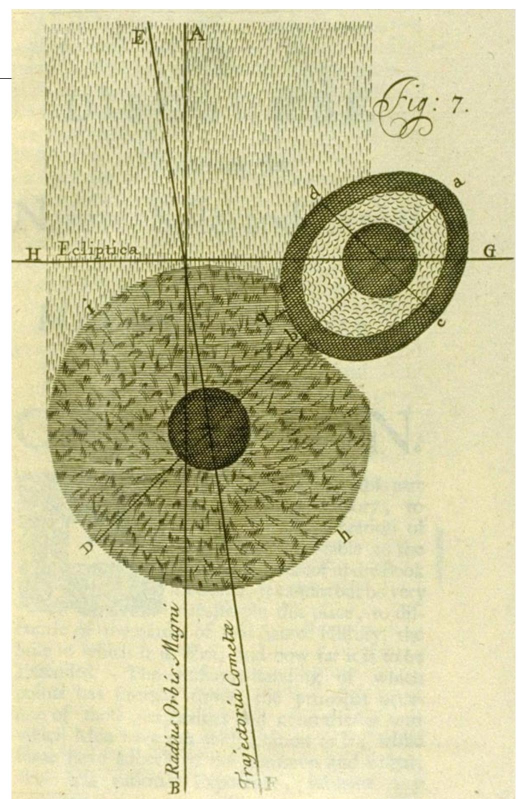


FIGURE 165. Whiston's *Figure 7*. First day of the deluge.

The Cartesian-Burnetian Earth, complete with subterranean abyss, is shown during the cometary pass in Figure 165. The comet's watery atmosphere engulfed the Earth, pouring rain through the "windows of heaven." On this first day of the deluge, gravitational tides distorted the Earth's spherical shape into an ovoid figure (exactly like Burnet's Paradisiacal globe). The crust shattered due to this gravitational attraction between the comet and the Earth, releasing the "fountains of the deep" from the watery abyss. In addition to providing a source for the diluvial waters and a means for cracking open the eggshell of the Earth's crust, the cometary pass at the time of the deluge changed the circular orbit of the Earth into an elliptical one and increased the length of the year by ten days.

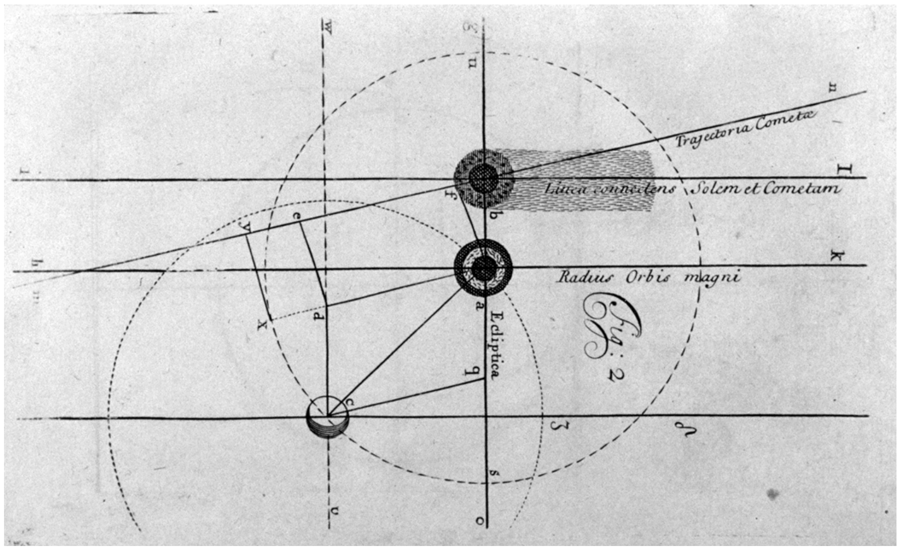


FIGURE 166. Whiston's *Figure 2*.

In Figure 166 Whiston showed the comet at its first pass near the Earth during its approach to the Sun. It is moving along a trajectory that is inclined both to the radius of the orbit of the Earth and to the direction of its tail (which falls in a line pointing away from the Sun). The Earth is the object in the middle, with its orbiting Moon just past New, approaching a First Crescent phase. Whiston analyzed how a cometary pass might occur in this configuration without disrupting the Moon's orbit around the Earth. After perihelion, as the comet ascended toward a second rendevous with the Earth, its tail continued to inundate the Earth while the heavenly waters "prevailed upon the Earth, an hundred and fifty days" (Genesis 7: 24) before abating.[340] Moreover, the first pass accelerated the velocity of the Moon while the second pass diminished it, ensuring the continued view from the Earth of the same side of the Moon but imparting to it some residual irregularities in its motion.

The phase of the Moon in *figure 2* is crucial, and the dates indicated in *figure 1* are important, for in Whiston's hands chronological and astronomical tables were combined to prove that none other than a comet recently described by Edmond Halley (though not the posthumously famous "Halley's comet") would have been in the right place at the right time to cause the Noachian deluge. Whiston remarked: "The very day of the Comets passing by, or of the beginning of the deluge determin'd from the Astronomical Tables of the Conjunctions of the Sun and Moon, is exactly coincident with that before nearly determin'd by the place of the Perihelion, and exactly by the Mosaick History."[341]

[340] Whiston considered whether a deluge must have occurred on the Moon at the same time, and reasoned that, as the diagrams show, vapors would only have fallen upon the Moon's far side, leaving the near side in its "ancient Purity and Clearness." John Wilkins' *The Discovery of a World in the Moone* (London, 1638), Book I, proposition 10, was cited as evidence for the vaporous character of the atmosphere of the far lunar hemisphere. Whiston, 366. Cf. the supposition of Nicholls, page 512.

[341] Whiston, 145. Similarly on p. 151: "When the very day of the beginning of the Deluge, nearly determin'd by the place of the Perihelion, and exactly by the Astronomical Tables of the Conjunctions of the Sun and Moon, is the very same individual Day with that mention'd by the Sacred Writer; hence arises a very surprizing and unexpected Confirmation of the Verity of the Scripture History. Here is a great and signal instance of the wonderful Providence of God indeed, and of his care for the Credit and Establishment of the Holy Books; that he has left us means sufficient, after above Four thousand Years, of examining and ascertaining the Veracity of the most Ancient of its Writers, and in one of the most scrupled and exceptionable Points of his Narration, that of the Universal Deluge; and that from unexceptionable Principles, the Astronomical Tables of the Celestial Motions. To how great a degree this thing will deserve the most serious Consideration of every one, especially in this our Sceptical Age, I need not determine. The importance of the concurr, and the greatness of the Evidence hence afforded, sufficiently enforcing this Point, without any farther Application."

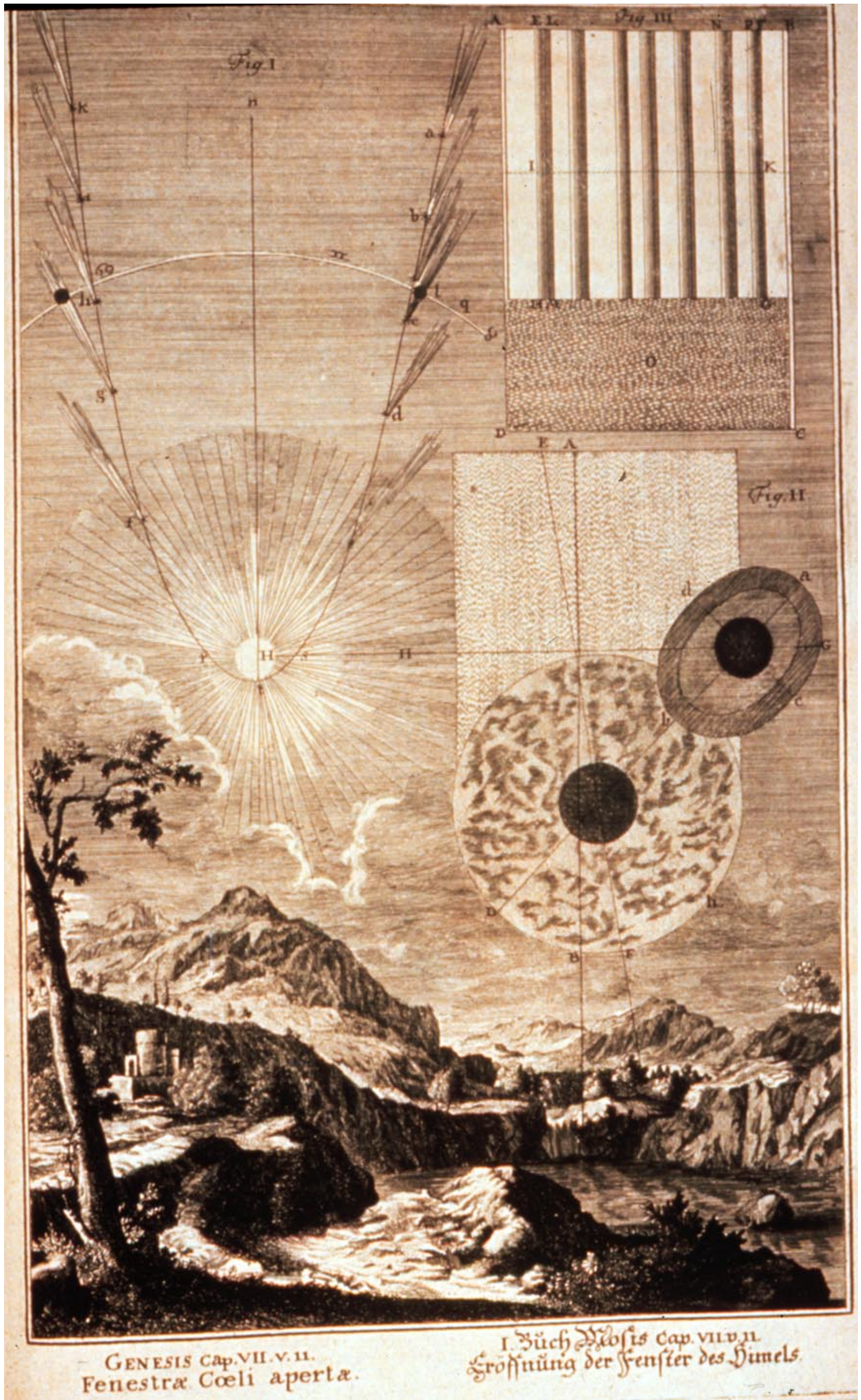


FIGURE 167. Scheuchzer's Deluge, *Physica Sacra*.

With Whiston's Theory the depiction of the Earth as an exterior crust surrounding a subterranean abyss has become a visual trope, an established convention, developed by Descartes and Burnet but now transposed into a rival natural philosophy. Comets were as important as they were for Descartes, but in an entirely Newtonian, anti-Cartesian manner. Whiston appropriated Burnet's Platonic antediluvian world and transposed it into his Hexameral system, which ended on the third day of the creation week and at the Fall, although just as in Burnet's Theory, it shattered at the deluge.[342] Nevertheless, in whatever context, didactic schemes of global sections have become recognizable, requiring less verbal explanation, the artistic conventions having become tacit (cf. Figure 167; note the combination of a landscape scene with Whiston's Figure 164 and Figure 165).

§ 9-vii. Burnet revisited: Establishment of Visual Traditions

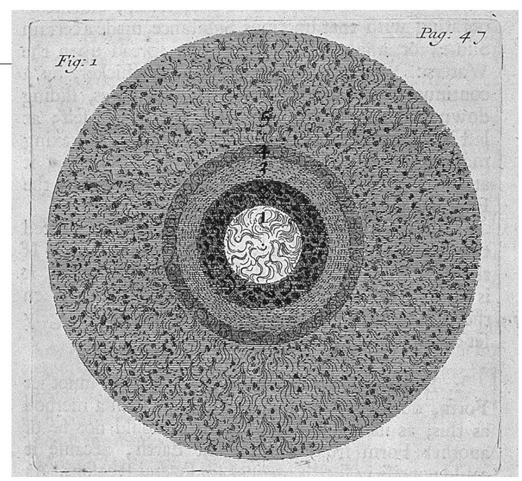


FIGURE 168. Warren's *Figure 1*. Summary of Burnet's geogonic series.

Long before Whiston's *New Theory of the Earth* (1696), Erasmus Warren published *Geologia* (1690), a critique of Burnet argued from a standpoint of traditional hexameral commentary. Warren's first diagram was a recapitulation of Burnet's sections, depicting five layers to summarize Burnet's account of the origin from

[342] Whiston's disjunction of Burnet's global section from Burnet's *Theory* was successful; for later readers the durability of Burnet's case for a vaulted abyss did not reflect widespread approval for the rest of Burnet's system. For example, while citing Burnet several times in his textbook of natural philosophy (and once charging that Pliny had more of religion than him), Cotton Mather's only favorable use of Burnet was to quote an elegantly-written paragraph that concludes: "Upon such a dreadful Abyss we walk, and ride, and sleep; and are sustained only by an arched Roof...." Cotton Mather, *The Christian Philosopher,* ed. Winton U. Solberg (Urbana: University of Illinois Press, 1994), 109–110; the non-attributed quotation is from Burnet, 96.

Chaos of the Paradisiacal world (Figure 168). Although Warren attempted to critique Burnet's account on the basis of (an inadequate understanding of) natural philosophy and Cartesian physics, he did not provide sections to illustrate an alternative view, but merely affirmed that God accomplished the creation in six twenty-four hour days.[343]

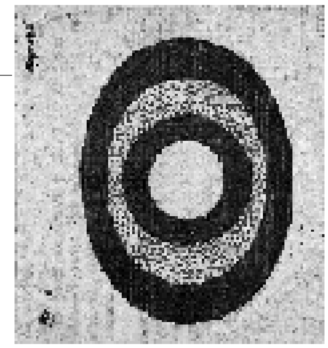


FIGURE 169. Warren's *figure 3*, Burnet's ovoid Earth. HSCI. (Axis rotated 90°.)

In two other diagrams Warren managed to demonstrate his complete misunderstanding of Burnet's Paradisiacal globe and the geometry of ovoid figures. He reprinted Burnet's oval section of the Earth (Figure 169) to accompany his speculation that, on Burnet's principles, the Earth might have tipped over, disrupting the coincidence of the ecliptic and celestial equator, long before the deluge.[344] Warren argued that an oval figure by definition must have a major axis one fourth longer than its minor axis, which would be sufficiently long to cause the polar areas to freeze into ice mountains instead of watery pools, contrary to Burnet's Paradisiacal water cycle.[345]

[343]Warren's global section contains the familiar Burnetian layers, starting from the inside: a fiery center, the interior orb, the watery abyss, an oily liquor upon the surface of the water, and the outer atmosphere. Warren spoke of 104° of latitude, as well as other geometrical absurdities, on which Keill discoursed for five pages, caustically remarking: "But I will leave Euclid to his mercy." Cf. Warren, p. 116, for the calculation that the poles are much colder if the Earth is oval instead of spherical. Keill was not impressed: "This is the first time I ever heard that there could be more than ninety degrees between the pole and the aequator but he thinks he has fairly made it out that there can be a hundred and four degrees between them...." No sensible alteration in temperature occurs, Keill explained, because the change in polar diameter is an insensible distance compared to the Earth's distance from the Sun. To "surprize him a little more," Keill explained that the distance from the Pole to the Sun varies by hundreds of thousands of miles between winter and summer because of the variation in the diameter of the earth's orbit. Keill, *Examination*, p. 24-25. Erasmus Warren, *Geologia: or, a Discourse Concerning the Earth before the Deluge. Wherein the Form and Properties ascribed to it, in a Book intituled The Theory of the Earth, Are Excepted Against: And it is made appear, That the Dissolution of that Earth was not the Cause of the Universal Flood. Also A New Explication of that Flood is attempted* (London: Printed for R. Chiswell, at the Rose and Crown in St. Paul's Church-Yard, 1690), 46–54. A fourth diagram used by Warren does not correspond with any of Burnet's illustrations.

[344]Warren, 186.

[345]Warren, 114–119. This attempt to refute Burnet by redefinition was illustrated by a geometrical drawing, but the argument is so spurious I have declined to reproduce it.

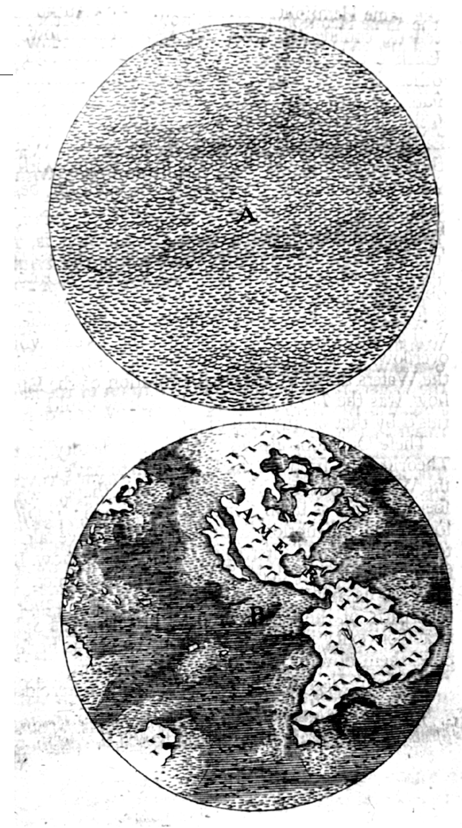


FIGURE 170. Beverley

A late defender of Burnet, Thomas Beverley, rose to Burnet's defense in response to the abusive wit of John Keill.[346] Two global views by Beverley appear to repeat Burnet's deluge and present world (Figure 170). However, with diagram *A* Beverley represented not Burnet's deluge (Noah's Ark and attending angels are omitted), but "the Earth, in its first state, when covered with Water." For Beverley Genesis 1 required that something like *A* must have existed; something like *B* now exists, so therefore some Theory is needed to go from one to the other: "The question will be, How this Orb of water came to be cover'd with dry Land, or came to be divided into Land and Water, as it is Now."[347] This Keill had not explained, so his criticisms were misdirected. The diminishing of the waters into the broken and shattered crust postulated by Burnet's Theory, Beverley suggested, avoided difficulties latent in any hypothesis for how the dry land might have been raised up out of the water. Beverley's work amounts to a defense of Platonic Theories of the Earth, for he insisted that the solid land must have originated as Burnet said, as a concretion upon the waters part of which collapsed, rather than forming underneath the waters and sometime thereafter being raised above.

[346]Thomas Beverley, *Reflections upon the Theory of the Earth, Occasion'd by a Late Examination of It. In a Letter to a Friend* (London: W. Kettilby, 1699).

[347]Beverley, 51.

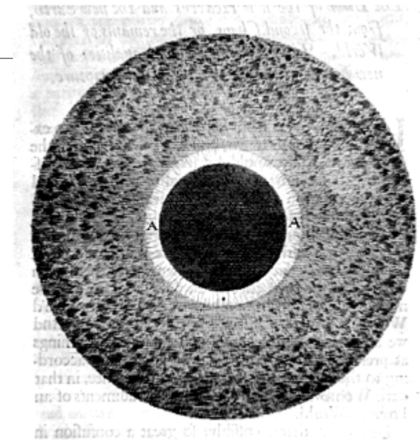


FIGURE 171. Burnet's conflagration.

Whiston, Warren and Beverley were not the only Theorists to find Burnet's global sections and views useful in different contexts. Burnet himself was one of the first, when in Book IV he described the formation of the Millennial Paradise from the remnants of the Conflagration. Another global section (Figure 171) represents a time subsequent to the conflagration global view on the frontispiece. In the diagram, A is a region of melted matter, an "Orb of fire" surrounded by a Chaos of mixed exhalations and a confusion of mingled elements. The melted mass of the orb of fire becomes encrusted with solid matter, enclosed about like a "molten Sea or Abyss." Burnet explained:

> Nature here repeats the same work, and in the same method; onely the materials are now a little more refin'd and purg'd by the fire. They both rise out of a Chaos, and That, in effect, the same in both cases; .... This Chaos upon separation, will fall into the same form and Elements: and so in like manner create or constitute a second Paradisiacal World.[348]

This section of the making of the Millennial globe confirms the versatility of the didactic visual tradition stemming from Descartes.

So why were some visual conventions so durable (cf. Table 61)? The origination of a visual tradition with shared representational conventions supported a common discourse and debate. This occurred despite the diversity of physical, cosmological, theological, and disciplinary orientations and the often heated polemics conducted within that tradition.[349] The Theory of the Earth tradition, an intellectual tradition of active criticism and debate, made

[348] Burnet, 324.

[349] Because of this visual durability, or adaptability into diverse textual habitats, such diagrams are of little value in tracing lines of conceptual influence (e.g., to conclude that Steno's cosmology was of primarily Cartesian derivation, or Whiston's of Burnet's, rather than a creative appropriation and transformation in a specific and localized context).

global sections like these (when the core as well as the crust were at issue) or local sections like Steno's (when the core was incidental) into boundary objects, a common currency, marketable by any participant in the tradition who might regard them as profitable for his own enterprise. Their value lay in their didactic utility tacitly to convey comprehensive global visions of the Earth and its changes through time.

The works of Descartes, Burnet, Steno and Whiston by no means exhaust the illustrations of historical importance in the tradition. In the following chapter brief descriptions of a number of later global sections, even without extended analysis, provide needed breadth to our portrait of Theories of the Earth. The variety among these visual representations reflects the diversity of the tradition itself.

TABLE 61. Two Conflagration Global Views from Scheuchzer's Physica Sacra

FIGURE 172. Scheuchzer, 2 Peter 3:7. LH.

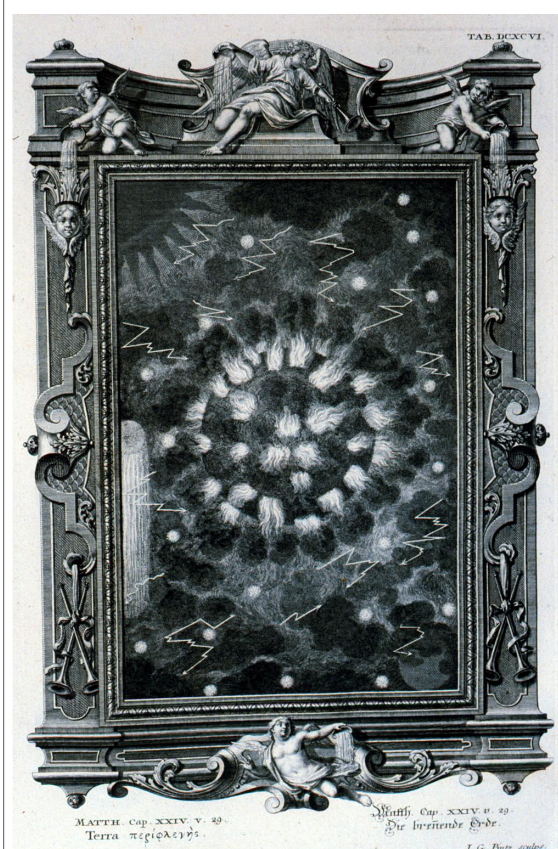


FIGURE 173. Scheuchzer, Revelation. LH.

§ 10. Baptizing Descartes

§ 10-i. The Hexameral Cosmogenesis of Robert Fludd

In this chapter we have seen that Descartes' Theory of the Earth employed global sections to depict the formation of the Earth in causal terms with a high degree of abstraction. Descartes cited visual representations and emblems as one of the most frequent sources of error in natural philosophy. Such error could be minimized, Descartes argued, by increasing the degree of abstraction.[350] Descartes' preference for abstraction becomes more understandable when contrasted with the most important set of visual precedents for depicting the creation available to him, which was provided by Robert Fludd in 1617.[351]

[350] Descartes remarked that depictions should not resemble their objects in very many respects. Rather, "a little ink placed here and there on a piece of paper, they represent to us forests, towns, people, and even battles and storms; and although they make us think of countless different qualities in these objects, it is only in respect of shape that there is any real resemblance. And even this resemblance is very imperfect, since engravings represent to us bodies of varying relief and depth on a surface which is entirely flat. Moreover, in accordance with the rules of perspective they often represent circles by ovals better than by other circles, squares by rhombuses better than by other squares, and similarly for other shapes. Thus it often happens that in order to be more perfect as an image and to represent an object better, an engraving ought not to resemble it." Quoted in Baigrie, "Descartes' Scientific Illustrations," 122 (AT VI, 113). In this illuminating study of mechanical illustrations, Baigrie argues that Descartes' abstract illustrations were involved in the creation of new knowledge (in present terms, didactic), and were neither mere visual aids (ornamental) to help the reader come to grips with the text nor clandestine importations of empirical elements (evidential) in an otherwise deductively rational endeavor. In contrast, we have seen that Burnet's illustrations were all of these.

[351] Robert Fludd, *De Macrocosmi Historia in duos tractatus diuisa,* vol. 1 of *Utriusque Cosmi Maioris scilicit et Minoris Metaphysica, Physica atqve Technica Historia, in duo Volumina secundum Cosmi differentiam diuisa,* 2 vols., (Oppenheim: Aere Johan-Theodori de Bry, 1617). The second volume was published in 1618. Important general studies of Fludd include J. B. Craven, *Doctor Robert Fludd* (Kirkwall: William Peace and Son, 1902; reprinted New York: Occult Research Press, n.d.); Allen G. Debus, *The English Paracelsians* (London: Oldbourne; New York: Franklin Watts, 1966); Allen G. Debus, *Robert Fludd and His Philosophicall Key* (New York: Science History Publications, 1979); Allen G. Debus, "Robert Fludd and the Use of Gilbert's *De Magnete* in the Weapon-Salve Controversy," *Journal of the History of Medicine* 19 (1964): 389–417; and C. H. Josten, "Truth's Golden Harrow, An Unpublished Alchemical Treatise of Robert Fludd in the Bodleian Library," *Ambix* 3 (1949): 91–150.

FIGURE 174. Robert Fludd, *Utriusque Cosmi Maioris* (1617), title page. LH.

Fludd, an English physician and loyal Anglican who dedicated his works to King James, became embroiled in controversies with Pierre Gassendi, Marin Mersenne, and Johannes Kepler, among others.[352] His works gained international notoriety and were well-known to continental natural philosophers.[353] As the ornate title page suggests, Fludd employed emblematic means of representation to convey mystical secrets from Hermeticism and the cabbala (Figure 174; compare with Figure 75 on page 425). The next several sections of this chapter summarize how Fludd used visual representations in a hexameral cosmogonic sequence.

[352]Robert Lenoble examines the controversy with Gassendi and Mersenne in *Mersenne ou la Naissance du Mécanisme* (Paris: Vrin, 1943). The controversy with Fludd has been explored by Wolfgang Pauli, "The Influence of Archetypal Ideas on the Scientific Theories of Kepler," in *The Interpretation of Nature and the Psyche,* trans. Priscilla Silz, ed. Carl G. Jung and Wolfgang Pauli, Bollingen Series no. 51 (New York: Pantheon Books, 1955); and by Robert S. Westman, "Nature, art, and psyche: Jung, Pauli, and the Kepler-Fludd polemic," in *Occult and scientific mentalities in the Renaissance*, ed. Brian Vickers (Cambridge: Cambridge University Press, 1984), 177–229. A general treatment of Fludd and the Rosicrucian controversies in found in Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago Press, 1964).

§ 10-i-a. Fludd's Hexameral Cosmogenesis, "In the Beginning"

FIGURE 175. Fludd, I.I., 26. Materia prima or hyle. HSCI.

Caption. "Et sic in infinitum."

Fludd's first cosmic section (Figure 175) is a square of darkness, representing the beginning of the creation.[354] Along the border on each side is written *Et sic in infinitum* ("and thus to infinity"). Before the creation there was a great void darkness. This *materia prima* or *hyle* was uncreated pure *potentia*, without quantity, dimension, qualities or other properties. The creation week was an alchemical actualization of this *hyle*. Fludd was rigorously criticized by Mersenne and others for appearing to make the *hyle* co-eternal with God.

[353]The fact that Descartes did not cite Fludd is not surprising, given the heated controveries engendered by Fludd's work. Speculation regarding Descartes' verifiable interest in Fludd and the Rosicrucians has run rampant. Baillet, Descartes' seventeenth-century biographer, reported that Descartes came to Paris to visit Father Marin Mersenne in 1623, at the very time two placards were announcing the imminent arrival of the secret society of Rosicrucians; Baillet suggested that the coincidental timing enhanced Descartes' reputation. Thus Descartes was welcomed by Mersenne, according to Baillet, at the very time Mersenne was writing his commentary on Genesis which includes lengthy criticisms of Fludd. See Adrien Baillet, *La Vie de Monsieur Des-Cartes,* 2 vols., *The Philosophy of Descartes*, ed. Willis Doney (Paris: Chez Daniel Horthemels, 1691; reprint New York: Garland, 1987), Book II, ch. 5, particularly pp. 108–109. Relying upon Baillet and other evidence, writers such as Dimitri Davidenko assert that Descartes in fact was a covert Rosicrucian! However, Baillet's account of Descartes' 1623 Parisian visit has been disproved by recent scholarship; cf. Geneviève Rodis-Lewis, *Descartes: His Life and Thought,* trans. Jane Marie Todd (Ithaca: Cornell University Press, 1998), especially p. 57. A critical guide to the literature on the Rosicrucians, which is sometimes as obscure and unreliable as the Rosicrucians' works themselves, is Brian Vickers, "Frances Yates and the Writing of History," *Journal of Modern History* 51 (1979): 287–316.

[354]Fludd, Tractatus I, Book I, Caput IV, "Materiae primae seu opificii universalis subjecti descripto," 24-26.

§ 10-i-b. Fludd's First Day, "Let there be Light"

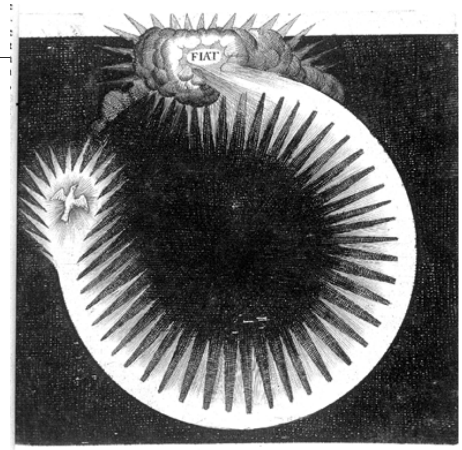


FIGURE 176. Fludd, I. I, 49. Divine Fiat. HSCI.

The first act of creation illumines and thereby forms the *materia prima*.[355] Illumination results as the Spirit moves upon the dark waters, proceeding from the divine *fiat*. The light of the Spirit transforms the *hyle* into a chaos of rude, undigested matter wherein the elements struggle and contend against each other. Three times the Spirit will proceed from God (a morning) and return to God (an evening) delineating the first three days.

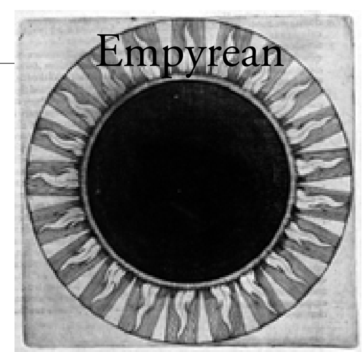


FIGURE 177. Fludd, I. II, 55. Empyrean heaven. HSCI.

On each of the first three days one of the three heavens is formed. In Figure 177 the highest empyrean heaven is formed on the first day.[356] This diagram is part of the second sequence of two sequences in which the upper waters are the focus instead of the lower waters (for brevity of exposition two hexameral series from Books I and II are here conflated into a single narrative). In this upper waters sequence successive passes of the light of the Spirit on the second and third days will form the second and third heavens.

[355] Fludd, Tractatus I, Book I, Caput II, "Quod Deus ante mundi creationem sibi ipsi tantum reluxerit: De dono amatorio, quod Deus hylae parti mundum conflanti dedit: Unde mundi figura sphaerica?", 45-49, and Caput III, "De tribus prioribus creationis diebus," 49-51.

[356] Fludd, Tractatus I, Book II, Caput V, "De coeli spiritualis basi, ejus compositione & natura, positionisque utilitate, 52-55. "Lvcis creatae primariae apparitio."

§ 10-i-c. Fludd's Second Day, Separation of the Waters

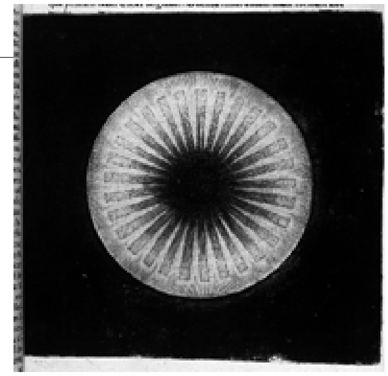


FIGURE 178. Fludd, I. I., 29. Middle (aetherial) heaven. HSCI.

Description. Lower waters sequence. The lower regions remain dark and without form beneath the newly-formed aetherial or middle heaven. The empyrean is not shown.[357]

On the second day the middle or aetherial heaven is formed (Figure 178, Figure 179 and Figure 180).[358] As

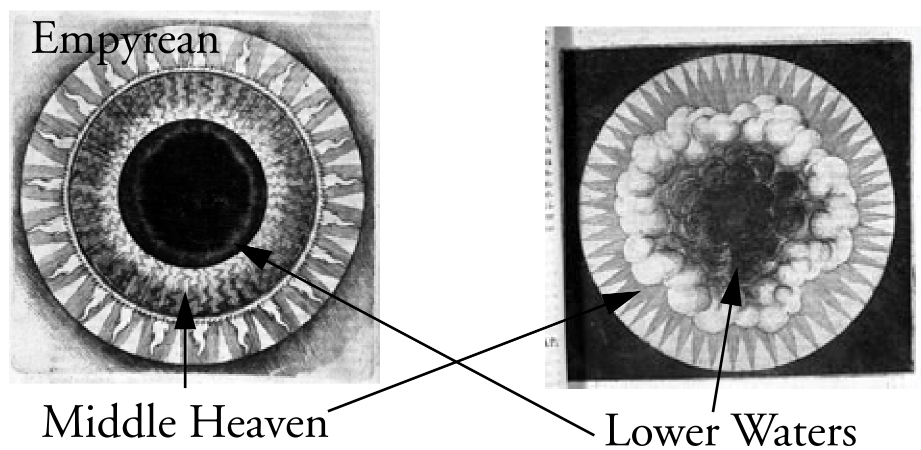


FIGURE 179. Fludd, I. II, 58. HSCI.

Description. Upper waters sequence. The middle heaven is shown beneath the empyrean heaven.

FIGURE 180. Fludd, I. I, 37. HSCI.

Description. Lower waters sequence. The middle heaven is outermost; the empyrean heaven is not shown.

[357]Fludd, Tractatus I, Book I, Caput VI, "De essentia universali, qua opifex opificii universalis materiam informavit," 27-33.

[358]For Figure 179; cf. Fludd, Tractatus I, Book I, Caput VIII, "Quod duo ad materiae primae existentiam concurrant: sub qua forma materia prima in actum reducta appareat? & quod sit aqua grossa & subtilis," 35-37. For Figure 180; cf. Book II, Caput VII, "Coeli medii compositio cur sphaera aequalitatis dicatur? quod haec regio respectu superioris coelum vocetur corporeum?" 57-58.

the light makes a second pass, the Chaos is divided into upper waters of heavenly fire (the aetherial heaven, located beneth the empyrean heaven), and the lower waters which are dark and passive (the dark central area of each figure). The middle heaven will contain the spheres of the planets and the fixed stars on the fourth day.

§ 10-i-d. Fludd's Third Day, Gathering of the Waters

FIGURE 181. Fludd, I. I, 41. Elemental Chaos. HSCI.

Description. Lower waters sequence. Meteorological section; aetherial and empyrean heavens not shown. Compare with central area of Figure 180.

With the creation of the two outer heavens on the first and second days (not shown in Figure 181), darkness now presses down upon the chaos of lower elements.[359] The creation proceeds as a successive extraction from the chaos by the operation of heavenly fire. At the beginning of the third day the elemental chaos, or lower waters, consists of three elements striving against one another: earth (cold and dry, corresponding to the mineral kingdom), humidity (moist and either hot or cold, corresponding to the vegetable kingdom), and fire (hot and dry, corresponding to the animal kingdom). By the end of the third day the lowest heaven is formed as earth, water, air, and fire are successively extracted from the chaos.

[359]Fludd, Tractatus I, Book I, Caput X, "De Chaos, & principiis creaturarum coeli infimi," 39-43.

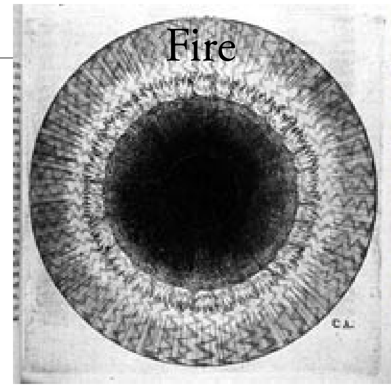


FIGURE 182. Fludd, I. II, 63. Extraction of fire. HSCI.

Description. Lower waters sequence; meteorological section; lowest region. Fiery element outermost. aetherial and empyrean heavens not shown.

Within the lower meteorological heaven shown as the dark center on previous figures, the fiery element (hot and dry) is extracted from the black mass of earth and moves to form the outermost of three elemental regions.[360] All things cold and humid are expelled from the region of fire into the center.

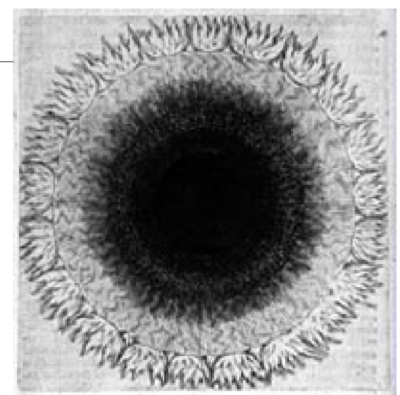


FIGURE 183. Fludd, I. II, 66. Extraction of earth. HSCI.

Description. Lower waters sequence; meteorological section; lowest region. Fiery element outermost. aetherial and empyrean heavens not shown.

As a result of its explusion from the sphere of fire (still the outermost layer depicted), cold elemental earth falls to the center (Figure 183).[361] Thus God has created the heavens and the earth, separating light from darkness, creating a suitable abode for the misery of postlapsarian humans and fallen spiritual beings.

[360]Fludd, Tractatus I, Book II, Caput XI, "De elemento ignis," 62-63.
[361]Fludd, Tractatus I, Book II, Caput XII, "De elemento terrae," 64-66.

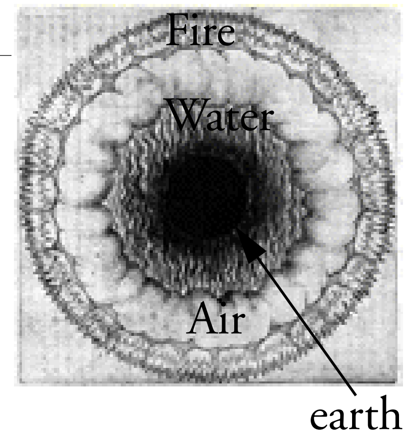


FIGURE 184. Fludd, I. II, 69. Extraction of air and water. HSCI.

Air and water are next extracted from the earth to form two intermediate layers between the outer fire and the central earth (Figure 184).[362] Water (cold and wet) surrounds elemental earth (cold and dry) and becomes in turn surrounded by clouds of air (hot and wet). The resulting diagram is a traditional Aristotelian meteorological section, and it represents the end of the third day.[363]

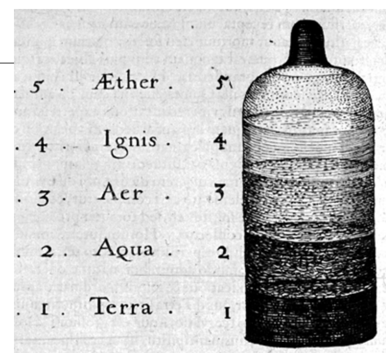


FIGURE 185. Fludd, I. II, 72. Five elements. HSCI.

When the darkness contracted to the degree that it could be called earth on the third day, an extraction of elements out of the primeval chaos was nearly complete. For Fludd the third day separated the dry earth not from the sea, as in typical hexameral illustrations, but from the waters in an alchemical sense; the elements were no longer mingled. Fludd insisted that this extraction, representing the first three days of creation, was replicated by his own experiments which yielded the same products (Figure 185).

[362]Fludd, Tractatus I, Book II, Caput XIII, "De sphaera media, quae sphaera humiditatis dicitur, & de elemento aquae & aëris," 66-69.

[363]In the number of concentric regions through the first four days, Fludd's sequence is remarkably similar to the hexameral illustrations of the *Nuremberg Chronicle* (1493). Cf. Table 48 on page 408.

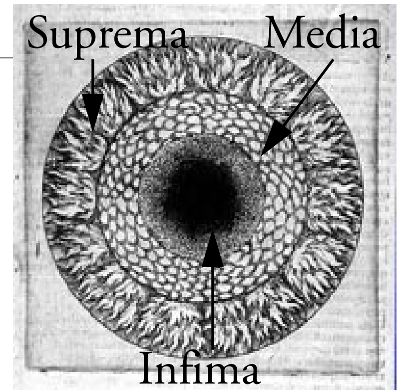


FIGURE 186. Fludd, I. II, 46. Three heavens. HSCI.

By the end of the third day the three heavens have formed, distinguished by decreasing purity moving from the outside in (Figure 186; compare Fludd's table of contents, Table 62).[364] The three heavens are not yet filled, but they are recognizable as follows:

- *Suprema*: The highest heaven, which terminates with the Trinity. It includes the *crystallinum* and *empyreum*.
- The aetherial *media*, which includes the sphere of fixed stars and spheres for each of the planets.
- The dark *infima*, which includes earth, water, air and fire.

TABLE 62. Three Regions of the Macrocosm

Heaven	Number of Parts, Constitution	Description of Parts, chapter
Suprema	Number of parts: 3	Trinitatis absque termino de quo, chs. 2-3
		Empyrean, ch. 3
		Cristallinum, ch. 4
	Constitution	Luce essentificia, & omnium simplicissima
		Spiritu purissimo, tenuissimo, & incomprehensibili, ch 5
Media aether	Number of parts: 8	Fixarum
		Erraticum (7)
	Constitution:	Luce substantiali mediocri Spiritu nec nimis grosso, nec nimis subtili, chs. 6–9
Infima ch. 10	Number of parts: 3	1. Extremae Superior, est ignis tabernaculum, ch. 11
		2. Extremae Inferior, est terrae sedes, ch. 12
		3. Media, sphaera humiditatis: Aëris, ch. 13
		3. Media, sphaera humiditatis: Aqua, ch. 13
	Constitution:	Lux tertiana & omnium grossior, chs. 14-15
		Spiritus omnium spissin & foeculentiar, chs. 14-15

[364]Fludd, Tractatus I, Book II, Caput I, "De mundo ejusque divisione," 45-46.

§ 10-i-e. Fludd's Fourth Day, Filling the Middle Heaven

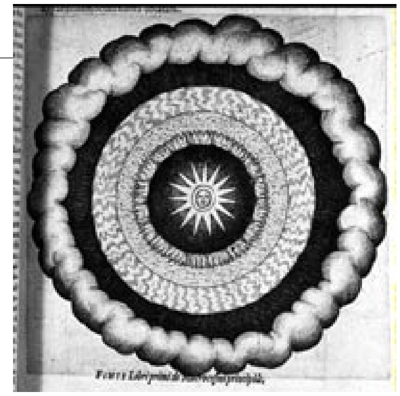


FIGURE 187. Fludd, I. I, 43. Extraction of aetherial bodies. HSCI.

Fludd reported that the aether or fifth element is the last to be expressed from the solid in an alchemical extraction (cf. Figure 185). Fludd's experiments produced a kernel of solar substance after performing the extractions. In the same way the Sun, destined for the middle of the middle heaven, appears from the womb of chaos only after the previous extractions of earth, water, air, and fire (Figure 187).[365] Thus Moses showed his adept mastery of chemical arts by designating the fourth day as the time when the Sun, Moon, and stars were made. Transported from the center by sublimation, they now fill the middle, aetherial heaven.

[365]Fludd, Tractatus I, Book I, Caput X, "De Chaos, & principiis creaturarum coeli infimi," 39-43.

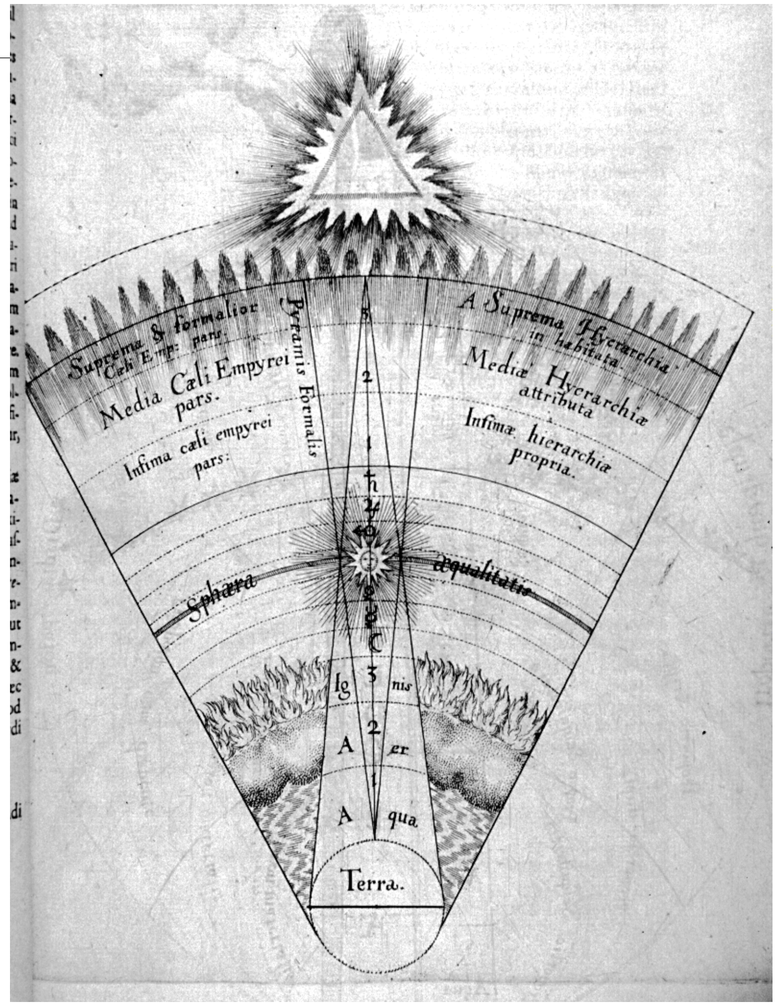


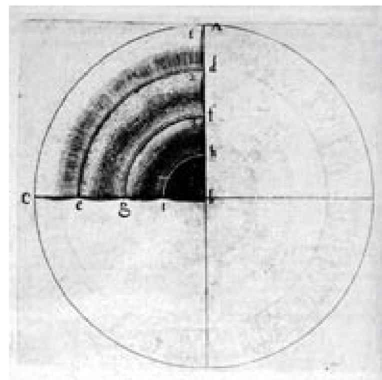
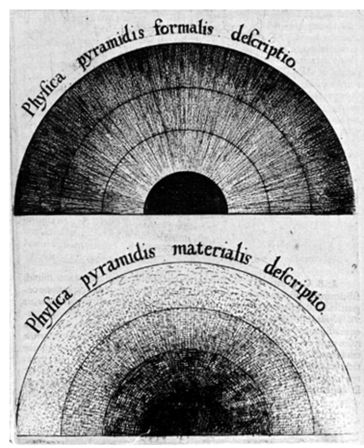
FIGURE 188. Fludd, I. III, 89. Material and formal pyramids. HSCI.

With the Sun transported to the middle of the middle heaven, it shines at a *Sphaera aequalitatie* between matter ascending from the Earth and form descending from the Empyrean heaven and the presence of God. This nexus is shown in the intersecting formal and material pyramids (Figure 188).[366]

Did Fludd's diagrams offer any specific visual conventions that were appropriated by Descartes? Two additional diagrams used by Fludd are worth noting (Table 63). To depict the density or rarefaction of matter and the distribution of form, Fludd employed double hemisections. The three outer layers are the empyrean, aetherial, and elemental realms (not fire, air, water, but the same three heavens as Beati and the Jesuits). Earth or pure matter lies at the center. Beyond the empyrean is pure form (matter extends no further). Matter and form are balanced in the aetherial sphere at the location of the Sun. These two diagrams bear

[366]Fludd, Tractatus I, Book III. A similar diagram appears in Caput XVII, "De oppositi formae & materiae universalium motus, & de ipsarum in quolibet coelo proportionis, verique Solis in coelo medio situs demonstratione efficacissima," 163-167.

TABLE 63. **Additional sections (Fludd)**

Tractatus Book, Page	Description	Image
I.II. p. 76	Quarter wheel	
I.V. p. 166	Hemispheres: Material and Formal principles “Physica pyramidis formalis descriptio” “Physica pyramidis materialis descriptio”	

an interesting formal resemblance to Descartes “wheel of time” (Figure 89 on page 459) and two hemisections (Figure 101 on page 476 and Figure 102 on page 476). However, there is no conceptual resemblance, since Descartes’ “wheel of time” is a comet section and his hemisections are global depictions, while Fludd’s diagrams are cosmic sections. Descartes was a covert assimilator who cast his nets widely. For example, Descartes conceded the possible reality of occult phenomenon in the well-known cases of magnetism and the weapon salve, and devised mechanical accounts to explain alleged effects without invoking occult causes. Similarly, he may have appropriated aspects of Fludd's visual demonstrations, which may not be as far from Descartes' diagrams as one might first suspect. It does not make Descartes a Rosicrucian to observe that a few of Fludd's cosmogonic sections could be relabelled and given a Cartesian spin.

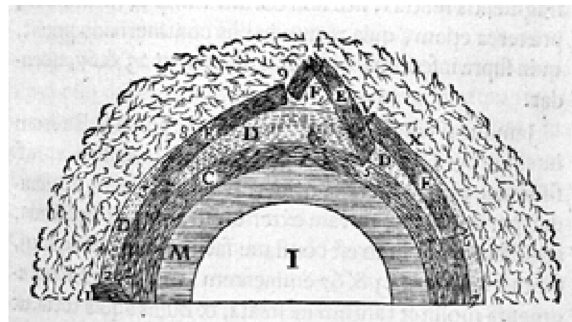
At a deeper level than any specific visual conventions historians have discussed the epistemology involved in the manipulation of hermetic emblems.[367] In contrast to Fludd's ornamental emblematic illustrations, however, these didactic cosmogonic sections provided a model of using visual representations to conceptualize and to demonstrate cosmogonical ideas, including an attempted reconciliation of the traditional four-element theories with Paracelsian three-element matter theories. Fludd found it nearly impossible to present his views without an abundance of illustrations. Indeed, in later works Fludd repeatedly referred back to the illustrations published in this volume to explain his cosmogony and interpretation of the hexameral account.

§ 10-ii. Genetic Development: The Epistemic Style of Descartes' Visual Rhetoric

Whether Descartes appreciated something of the didactic potential of visual demonstration as a result of reading Fludd or not, in at least one respect Descartes' and Fludd's cosmogonies were directly antithetical: where Fludd offered an obscure and ambiguous esoteric vision, Descartes provided a clear and distinct natural philosophy. The clarity of Descartes'

[367] This latter issue lay at the heart of Fludd's dispute with Kepler. In *Harmonices mundi* (1619) Kepler was adamant that his musical astronomy was utterly different than Fludd's views of the heavenly harmonies: "First, what [Fludd] endeavors to teach us as harmonies are mere symbolism. Of them I say what I said of Ptolemy's symbolism, that they are poetic or rhetorical rather than philosophical or mathematical. This is the spirit of his whole work...." Johannes Kepler, *The Harmony of the World,* trans. E. J. Aiton, A. M. Duncan and J. V. Field, (Philadelphia: American Philosophical Society, 1997), appendix to book V, p. 505. See the citations noted in footnote 352 on page 603.

first principles, coupled with the disciplines of logical demonstration, validated the claim to certain and accessible knowledge by which Descartes distinguished himself from esoteric philosophers. Dispensing with citation of textual traditions in contrast to hermetic philosophers, Descartes' visual rhetoric also contrasted with Fludd's by utilizing absolutely no emblematic signs but only didactic diagrams employing geometrical or mechanical conventions.



In his visual demonstrations, Descartes claimed to derive all of the layers in his cosmogonic sections as necessary stages in the work of physical laws upon chaos. Only when the diagrams were complete and their physical processes fully reasoned through from clear and certain foundations did he reveal to the reader the actual features of the Earth to which the last diagram referred, by identifying layers B and F with air, layer D with water, layer E with the exterior crust and layer C with the interior crust of the Earth (cf. Figure 102 on page 476, reproduced here).[368] Thus did Descartes rigorously preserve the appearance of reasoning strictly *propter quid* from causal principles, with no reliance upon prior knowledge of the effects to be demonstrated.[369]

§ 10-ii-a. Genesis and the Rhetoric of Demonstration

Descartes' visual rhetoric was consistent with his verbal rhetoric of causal reasoning from first principles. According to Descartes a proper theory is a set of causal demonstrations.

368 Descartes, *Principles of Philosophy*, Part IV, Article 44, p. 203. Figure X.

369 This is not to claim that Descartes' physics, as distinct from his visual rhetoric, was truly a priori or without prior knowledge of the effects, for the phenomena of the heavens and Earth considered in Parts III and IV were largely derived from ordinary experience and common knowledge. Moreover, Descartes conceded that experimentation and systematic observation would be necessary as soon as one descended into more particular inquiries. (see below) It is also important to keep in mind that Descartes' methodological practice and his methodological rhetoric should be distinguished; cf. John A. Schuster, "Whatever Should We Do with Cartesian Method? Reclaiming Descartes for the History of Science," in *Essays on the Philosophy and Science of René Descartes*, ed. Stephen Voss (Oxford: Oxford University Press, 1993), 195-223.

Descartes' explanations do not begin with phenomena (demonstration *quia*), but make phenomena intelligible only when they are seen as effects arising from necessary causes (demonstration *propter quid*).[370] In Part I of the *Principles of Philosophy*, Descartes began with clear and distinct ideas to ground the principles of human knowledge or metaphysics. Upon this foundation he then established, in turn, a system of physics (Part II), cosmology (Part III), and finally the section "on the Earth" (Part IV).[371]

Descartes' cosmological Part III begins with a declaration that his explanations of "all the phenomena of nature" are causal and deduced from first principles:

> We have discovered certain principles concerning material things; and there can be no doubt about the truth of these principles, since we sought them by the light

[370]For *propter quid* reasoning see Table 5 on page 32. The characterization of Descartes' *Principia* (or at least his Theory of the Earth) as deductive and causal is not straightforward. Although I make no similar claim regarding Descartes' other works or those of later Cartesians, yet even so qualified this claim has been contested because Descartes manifestly relied on observation, experimentation, and dissection as starting points for many of his inquiries into particular topics (such as the rainbow and the circulation of the blood). Nevertheless, the presentation of explanations within the purview of the *Principles of Philosophy* is explicitly deductive: "For we wish to deduce the effects from their causes rather than the causes from the effects" (Part III, Article 4, p. 85). Although adequately to consider this issue goes beyond the bounds of my argument here, there is no contradiction between Descartes' causal and deductive theories in physics and his use of experimentation for at least two reasons. First, using Descartes' explanation of the rainbow as a test case, Daniel Garber argues persuasively that experiment and observation functioned for Descartes not as a replacement for deduction, but as "part of the step preliminary to making a deduction." Experiments help to determine which directions deduction should follow, yet the phenomena remain uncertain until they are deduced from first principles. Precisely the same claim may be made for the epistemological role of didactic geometrical illustrations. Garber's informative article surveys some of the pertinent (and opposing) literature; Daniel Garber, "Descartes and Experiment in the *Discourse* and *Essays*," in *Essays on the Philosophy and Science of René Descartes*, ed. Stephen Voss (Oxford: Oxford University Press, 1993), 288-310. Second, Descartes observed that one must call upon experiments to assist a train of deductive reasoning when one descends to more particular and specific phenomena. Yet in the *Principles of Philosophy* Descartes did not "descend to particulars" to the degree where abundant experimentation was necessary. Both the *Discourse on Method* and the *Principles of Philosophy* support this claim. In the *Discourse on Method*, Part VI, Descartes explained that experiments are most useful when one has descended to a certain level of particularity. He noted that a Theory of the Earth does not descend that far: "But the order I have held to has been the following. First, I tried to find in a general way the principles or first causes of all that is or can be in the world, but not considering anything to this end except God alone who created the world, and not drawing these principles from any other source but from certain seeds of truth that are in our souls. After this I examined which ones were the first and most ordinary effects that could be deduced from these causes; it seemed to me that I had thus found the heavens, stars, an earth, and even, on the earth, water, air, fire, minerals, and other things that are the most common of all and the simplest—and hence the easiest to know. Then, when I wanted to descend to the more particular ones, so many different ones were presented to me that I did not believe it possible for the human mind to distinguish the forms or species of bodies that are on the earth from an infinity of others that could have been—had it been the will of God to put them there—or, as a consequence, to make them serviceable to us, unless one goes ahead to causes through effects and makes use of many particular experiments." René Descartes, *Discourse on Method*, trans. Donald A. Cress (Indianapolis: Hackett Publishing Company, 1980), 34. Thus the character of an Earthlike planet is deducible from causes; the actual existence of extra-terrestrial inhabitants or a Plurality of Worlds requires a knowledge of effects. In the *Principles of Philosophy*, Descartes indicated that two additional parts on Plants and Animals and on Man, which he would have liked to have included after the Theory of the Earth, required much further experimentation (Part IV, Article 188).

> of reason and not through the prejudices of the senses. We must now consider whether we are able to explain all the phenomena of nature by these principles alone....[372]

One could not ask for a clearer statement of the *propter quid* ideal of scientific knowledge. Eschewing quia and regressus forms of argument, as well as phenomenalism, it is not surprising that Descartes favored genetic explanations. He argued that to know an object one should understand the ordinary causes by which it was formed and by means of which something like it can even now come to be. As Jacques Roger aptly put it, Descartes offered a *genesis* rather than a *history*.[373] A genetic account does not claim to provide a history of the particular thing but only an explanation of the *formation* of that *kind* of thing—even if the explanation is false considering how a particular thing actually formed.[374]

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[371]Descartes' use in the Preface of a metaphor of knowledge as a tree with trunk and branches is well-known, and conveys Descartes' views in the *Principles of Philosophy* of the order and progression of the natural sciences (cf. Table 27, "Order of the Sciences: Aristotle and Descartes," on page 222). After first studying morals, logic, and mathematics, one should proceed to "true Philosophy, the first part of which is Metaphysics, which contains the Principles of knowledge; among which is the explanation of the principal attributes of God, of the immateriality of our souls, and of all the clear and simple notions which are in us [Part I]. The second is Physics, in which, after having discovered the true Principles of material things [Part II], one examines, in general, the composition of the whole universe [Part III], and then, in particular, the nature of this Earth and of all the bodies which are most commonly found around it, like air, water, fire, the loadstone, and the other minerals [Part IV]. After this, it is also necessary to examine in particular the nature of plants, of animals, and above all, of man; in order to be capable of subsequently discovering all the other useful branches of knowledge. Thus, Philosophy as a whole is like a tree; of which the roots are Metaphysics, the trunk is Physics, and the branches emerging from this trunk are all the other branches of knowledge." Descartes, *Principles of Philosophy*, Preface, p. xxiv (bracketed notes are mine). This order and sequence differs from that followed at the Jesuit university of La Flèche where Descartes was taught. The three-year philosophy curriculum at La Flèche began with ethics and logic in the first year; included physics and metaphysics in the second year; and concluded with mathematics in the third year. Cf. Roger Ariew, "Descartes and Scholasticism: The Intellectual Background to Descartes' Thought," in *The Cambridge Companion to Descartes*, ed. John Cottingham, 58–90 (Cambridge: Cambridge University Press, 1992), 60. Daniel Garber discusses the novelty and reception of Descartes' claim that metaphysics precedes and is a foundation for physics in Daniel Garber, *Descartes' Metaphysical Physics* (Chicago: University of Chicago Press, 1992), esp. 61-62.

[372]Descartes, *Principles of Philosophy*, Part III, Article 1, p. 84.

[373]Jacques Roger, "The Cartesian Model and Its Role in 18th-century Theory of the Earth," in *Problems of Cartesianism*, ed. Thomas M. Lennon, John M. Nicholas and John W. Davis, McGill-Queen's Studies in the History of Ideas, ed. Richard H. Popkin (Kingston: McGill-Queen's University Press, 1982), 101. Hereafter Roger, "Cartesian Model." The distinction between genetic and historical sensibilities was introduced with a discussion of propter quid, quia, regressus, and phenomenalist epistemic aims in Chapter 1, "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

[374]Genetic explanations in natural philosophy are therefore analogous to rational reconstructions in historiography; see the discussion in "Lyell and Histories of Scientific Disciplines," beginning on page 280.

Because of the omnipotence and perfection of God, for Descartes any particular thing may have been created *de novo* or at once, just as Adam and Eve were created mature in a garden already perfect in its fruits. Nevertheless, to understand a man, an Earth, a solar system, or any thing in general, one should try to grasp how such a thing could have been formed through the ordinary operation of causal processes. The fact that Adam, the universe, or the Earth may have originated by divine *fiat* rather than actually proceeding through the stages of a causal genetic account does not detract from the truth of the genetic account in its implications for the present structure and nature of the thing. The possible exercise of the absolute power of God does not reduce a genetic account to the status of a simple hypothetical model: by his absolute power God created them mature, but he still created them according to their natures, which are truly and most comprehensively represented by the genetic explanation.[375]

Descartes argued that causal genetic explanations were not only desirable, but within reach. By means of his physics a cosmologist could begin with chaos and deduce the present world:

> these laws of nature are such that, even if we were to assume the Chaos of the poets, that is, a total confusion of all parts of the universe; we could still demonstrate that, by these laws, this confusion must gradually be transformed into the order which is at present in the world.[376]

[375]Descartes, *Principles of Philosophy*, Part III, Article 45, p. 105-106: "Indeed, in order to better explain natural things, I may even retrace their causes here to a stage earlier than any I think they ever passed through. For example, I do not doubt that the world was created in the beginning with all the perfection which it now possesses; so that the Sun, the Earth, the Moon, and the Stars existed in it, and so that the Earth did not only contain the seeds of plants but was covered by actual plants; and that Adam and Eve were not born as children but were created as adults. The Christian faith teaches us this, and natural reason convinces us that this is true; because, taking into account the omnipotence of God, we must believe that everything He created was perfect in every way. But, nevertheless, just as for an understanding of the nature of plants or men it is better by far to consider how they can gradually grow from seeds than how they were created entire by God in the very beginning of the world; so, if we can devise some principles which are very simple and easy to know and by which we can demonstrate that the stars and the Earth, and indeed everything which we perceive in this visible world, could have sprung forth as if from certain seeds (even though we know that things did not happen that way); we shall in that way explain their nature much better than if we were merely to describe them as they are now, or as we believe them to have been created." Article 47 defends the claim that deductions from such falsehoods are nevertheless true and certain. Cf. *Descartes' Conversation with Burman*: "Everything in a chimera that can be clearly and distinctly conceived is a true entity. It is not fictitious, since it has a true and immutable essence, and this essence comes from God just as much as the actual essence of other things." Trans. Cottingham, 343. The desirability of genetic explanations is repeated throughout the *Principles*; cf. Part IV, Articles 1, 5, and 84.

[376]Descartes, *Principles of Philosophy*, Part III, Article 47, p. 107.

Descartes regarded his physics as the product of a long chain of deduction, and therefore certain. If mathematical certainty was not possible in view of the absolute power of God, he suggested its general features were better than morally-certain.[377] The natural order which Descartes found it possible to deduce included not only the physics of remote regions (Part III), but also of phenomena accessible to us (Part IV):

> In addition to these rather general things, I could also include here, among the phenomena, several other specific things, concerning not only the Sun, the Planets, the Comets, and the fixed Stars, but also the Earth: that is, everything which we see around the Earth, or which occurs on its surface. For indeed, in order to know the true nature of this visible world, it is not sufficient to find some causes by which one can explain what appears in the heaven very far from us; *it is necessary also to be able to deduce from them the things we see very close to us and which affect us more noticeably.*[378]

For Descartes, then, the Theory of the Earth both continuously extended and simultaneously corroborated metaphysical principles and causal theories in physics and cosmology. Thus, in the Cartesian system, the Theory of the Earth became differentiated from cosmology and was invested with equal philosophical significance.[379] By designating knowledge of the Earth as a philosophical discourse distinct from discussion of similar topics in cosmology, geography, meteorology or biblical theology Descartes' work marks an historically important precedent. In the penultimate conclusion of the treatise Descartes claimed that readers were able to conclude from his Theory of the Earth as well as from his cosmology that his principles of philosophy were certain, "deduced in a continuous series from the first and simplest principles of human knowledge."[380]

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[377] Descartes suggested that his Theory was better than morally certain in *Principles of Philosophy*, Part IV, Article 206 (cf. Articles 204-205). While contemporary critics (and modern historians), not impressed with the pretensions of mechanical philosophy to explain all the phenomena of the world, regarded Cartesian Theories of the Earth as "speculative," this characterization should not obscure Descartes' own self-presentation of his Theory as reliable deductive knowledge.

[378] Descartes, *Principles of Philosophy*, Part III, Article 42, p. 104. Italics added.

[379] This is similar to Descartes' deployment of mechanical physiology: "So central was the example of the heartbeat to Descartes that he said that if what he had written about the heart was wrong, then so was the rest of his philosophy." Roger French, *William Harvey's Natural Philosophy* (Cambridge: Cambridge University Press, 1994), 184.

Although Aristotle regarded causal knowledge (demonstration *propter quid*) as ideal, unlike Descartes he insisted that knowledge begins with sense perception and he accepted the legitimacy of demonstrations from the effects (*quia*) when true causes are unknown.[381] Meteorological phenomena, Aristotle conceded, were difficult to account for with demonstrative rigor, even reasoning *quia* from the phenomena: "some we find inexplicable, others we can *to some extent* understand."[382] In contrast to the certainty attainable in previous areas of inquiry such as cosmology, for Aristotle the vagaries of existence below the Moon made this realm susceptible only of approximate knowledge.[383] Given the subject, Aristotle conceded that something less than a demonstrative ideal, would be necessary: "We consider that we have given a sufficiently rational explanation of things inaccessible to observation by our senses if we have produced a theory that is possible (ἀναγάγωμεν)."[384]

Seen in this light it appears that Descartes' emphasis on the philosophical significance of his Theory of the Earth, with its genetic and causal, *propter quid* demonstrations of sublunar phenomena, deliberately contrasts the capacity and efficacy of his natural philosophy to Aristotle, whose cosmology may once have been deemed certain but whose meteorology was acknowledgedly nondemonstrative.[385] The similarity of Aristotle's nondemonstrative aim with some of Descartes' pronouncements should not be misinterpreted: Aristotle abandoned the demonstrative ideal because of the uncertainty of the subject matter; Descartes empha-

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380 Descartes, *Principles of Philosophy*, Part IV, Article 206, p. 287. This analysis of the epistemological status of Descartes' Theory agrees with François Duchesneau's emphasis on its rational intelligibility and putative certainty against Jacques Roger's description of it as merely possible hypothetical modeling, although Duchesneau mistakenly attributes a hypothetico-deductive model to Descartes which Roger successfully refutes; cf. François Duchesneau, "The Role of Hypotheses in Descartes's and Buffon's Theories of the Earth," in *Problems of Cartesianism*, ed. Thomas M. Lennon, John M. Nicholas and John W. Davis, McGill-Queen's Studies in the History of Ideas, ed. Richard H. Popkin (Kingston and Montreal: McGill-Queen's University Press, 1982), 119; and Jacques Roger, "Cartesian Model," 100. On the deductive form of the *Principia* cf. footnote 370 on page 616.

381 On demonstrations *quia* and *propter quid* see page 31 ff.

382 Aristotle, *Meteorology*, I.I., p. 5. Italics added.

383 See "Case 1: The Meteorological Tradition," beginning on page 222.

384 Aristotle, *Meteorology*, I.VII, pp. 48-49. Although this concession was made in the particular context of Aristotle's explanation of comets, it reflects his general approach to meteorological topics.

sized the intelligibility of the subject matter and only departed from the demonstrative ideal for theological reasons. When acknowledging that the absolute power of God made his Theory less certain than a mathematical demonstration, Descartes cited the above passage of Aristotle's *Meteorology* to defend the superiority of his account, suggesting that while neither were mathematically certain, his was better than morally certain.[386] Compared with Aristotle, Descartes extended the reach of demonstrative knowledge of the Earth: both the Earth as a whole and its individual phenomena were necessary or morally certain. Thus, contingency is minimized in the Cartesian genesis of the Earth, lying only in the initial choice of the preternatural will of God when he created the cosmos and thus instituted geogonic processes.[387]

Thus Descartes presented his Theory of the Earth in topical sequence to correspond to Aristotle's *Meteorology*, in content to replace it point-for-point with mechanistic explanations, and to surpass it in both philosophical significance and epistemic authority. In effect, by establishing the discourse of the Theory of the Earth, Descartes reinvigorated the meteorological tradition with a bolder epistemic ideal.

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[385]Descartes was not the first to differ with Aristotle on the epistemic status of sublunar knowledge, for the examle of Seneca's *Natural Questions* provides three interesting contrasts (cf. page 235). First, for Seneca as a Stoic in contrast to Aristotle, nothing happens by chance, not even below the Moon (175): "lightning bolts are not sent by Jupiter but all things are so arranged that even those things which are not done by him none the less do not happen without a plan, and the plan is his." Second, Seneca expressly applied the concept of natural laws (*iura naturae*) both to meteorology and to subterranean phenomena (e.g., pp. 238–239: "There are also laws of nature under the earth, less known to us but no less fixed"). Finally, when Seneca urged the study of the natural and usual rather than the rare and fortuitous (p. 187, an oft-quoted maxim in the eighteenth-century), it appears that he was not making a universal methodological prescription for the dissolution of the universe and the coming destruction of humanity (which occupied much of his attention) comes about through a rare conjunction of causes and appears fortuitous to us despite its hidden design. Just as moral dissolution in Stoicism occurs by a transgression of moral limits, so physical desctruction occurs by a transgression of natural limits. (See Book III, particularly pp. 285 and 293 ff.) Lucius Annaeus Seneca, *Naturales Quaestiones I,* trans. Thomas H. Corcoran, Loeb Classical Library, no. 450 (Cambridge: Harvard University Press; London: Heinemann, 1971).

[386]Descartes, *Principles of Philosophy*, Part IV, Articles 204, 205, and 206. Significantly, this is the only time Descartes quoted Aristotle in the *Principles*. Descartes' concession of less than mathematical certainty should not be interpreted as an escape clause to allow him hypothetically to affirm the motion of the Earth; rather, he denied the motion of the Earth given a definition of place as relative to the containing body, since the Earth never departs from the vortex that contains it. Cf. *Principles of Philosophy*, Part III, Article 29. In a letter written in 1644 upon publication of the *Principia*, Descartes mentioned both the passage quoted from Aristotle and the motion of the Earth. However, he denied the necessity of defending himself regarding the motion of the Earth by means of the Aristotelian passage, since he asserted that he did not affirm the motion of the Earth. René Descartes, *The Correspondence*, trans. John Cottingham, Robert Stoothoff, Dugald Murdoch and Anthony Kenny, vol. 3 of *The Philosophical Writings of Descartes*, 3 vols. (Cambridge: Cambridge University Press, 1991), 239; translated from *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery (Paris: Librairie Philosophique J. Vrin, 1965), vol. 5, 549-550.

§ 10-iii. Directionalist History: The Epistemic Style of Burnet's Visual Rhetoric

While seventeenth and eighteenth century Theories of the Earth for the most part shared these topics and similarly invested them with significance and authority, other Theorists did not follow the Cartesian approach in every way. In particular, while agreeing with the imperative of achieving epistemically-sound natural knowledge of the Earth, many did not agree that the Cartesian method provided the surest recipe for attaining that end. A clear instance is Thomas Burnet, who in epistemological method remained a classical scholar rather than a Cartesian philosopher; accordingly, his Theory of the Earth relied upon humanist traditions as well as reasoning from causes. As a result, as Roger argued, Burnet's Theory of the Earth represents the emergence of a perspective of directionalist historical change in opposition to both Cartesian genetic cosmogony and Aristotelian eternalistic meteorology.

After discussing Descartes' "mechanical mineralogy" and analyzing some of his illustrations, David Oldroyd comments that "the very diagrams of Burnet's widely-read *Sacred Theory of the Earth* are clearly (and crudely) beholden to Descartes's *Principia*."[388] Burnet's geogonic series of global sections depicting the original rise from chaos of a habitable Earth was "clearly beholden" to Descartes, as we have shown in detail. Moreover, Burnet appropriated the Car-

[387]There are two other respects in which the formation of a Cartesian Earth is contingent: First, the laws of physics by which the Earth was formed were freely instituted by God, as were mathematical truths. Second, the created order possesses only a contingent duration of existence, due to God's moment by moment conservation of the secondary causes at work. Yet given divine immutability, Descartes could know with moral certainty that the temporal trajectory followed by an Earth-like body in its formation would be exactly as he envisioned. Descartes' view that natural laws and eternal truths, including mathematical necessities, were created in the mind of God and therefore are contingent is analyzed in Edward Bradford Davis, Jr., "Creation, Contingency, and Early Modern Science: The Impact of Voluntaristic Theology on Seventeenth Century Natural Philosophy" (Ph.D. dissertation, University of Indiana, 1984). Chapter 3 was revised as "God, Man and Nature: The Problem of Creation in Cartesian Thought," *Scottish Journal of Theology* 44 (1991): 325-348. Davis also explicates Descartes' views of the contingent duration of the world, and regards Descartes as a voluntarist who emphasized the contingency of the natural order. Without disputing Davis' explication of these particular topics, the present analysis confirms the contrary overall assessment of Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994), cf. p. 126. Osler regards Descartes as an intellectualist who deemphasized contingency by restricting it to the preternatural will of God, leaving everything else to the necessary operation of natural causes.

tesian ideal of a Theory of the Earth as a deductive, genetic, and causal inquiry: "all this hath been deduc'd in due order, and with connexion and consequence of one thing upon another, so far as I know, which is the true evidence of a Theory; . . . ."[389] Burnet also echoed Descartes' emphasis on how one may have certainty of one's first principles if the comprehensive variety of natural phenomena may be deduced from them:

> And there is no surer mark of a good Hypothesis, than when it doth not only hit luckily in one or two particulars, but answers all that it is to be appli'd to, and is adequate to Nature in her whole extent.... and if that Hypothesis be easie and intelligible, and answers all the Phaenomena of those two bodies [a comet or the Sun], you have done as much as a Philosopher or Humane reason can do. And this is what we have attempted concerning the Earth and concerning the Deluge; We have laid down an Hypothesis that is easie and perspicuous, consisting of a few things, and those very intelligible, and from this we have given an account how the Old World was destroyed by a Deluge of water, and how the Earth came into this present form;....[390]

[388]David Oldroyd, "Mechanical Mineralogy," *Ambix* 21 (1974): 166; the parenthetical comment is Oldroyd's. This single sentence is the only consideration of Burnet in the article. It is interesting to note that in his recent and comprehensive survey of the history of geology, Oldroyd did not bother to mention Burnet at all; David Oldroyd, *Thinking about the Earth: A History of Ideas in Geology* (Cambridge: Harvard University Press, 1996). This slight of Burnet is consistent with his Foucauldian denial of any role played by Theories of the Earth in the development of geohistorical sensibilities.

[389]Burnet, 71. Another passage commends genetic theories and employs the Cartesian metaphor of first principles as the seeds of the knowledge which may be deduced from them: "Neither is it perhaps such an intricate thing as we imagine at first sight, to trace a Chaos into an habitable World; at least there is a particular pleasure to see things in their Origin, and by what degrees and successive changes they rise into that order and state we see them in afterwards, when compleated. I am sure, if ever we would view the paths of Divine Wisdom, in the works and in the conduct of Nature, we must not only consider how things are, but how they came to be so. 'Tis pleasant to look upon a Tree in the Summer, cover'd with its green Leaves, deckt with Blossoms, or laden with Fruit, and casting a pleasing shade under its spreading Boughs; but to consider how this Tree with all its furniture, sprang from a little Seed; how Nature shap'd it, and fed it, in its infancy and growth; added new parts, and still advanc'd it by little and little, till it came to this greatness and perfection, this, methinks, is another sort of pleasure, more rational, less common, and which is properly the contemplation of Divine Wisdom in the works of Nature. So to view this Earth, and this Sublunary World, as it is now compleat, distinguisht into the several orders of bodies of which it consists, every one perfect and admirable in its kind; this is truly delightful, and a very good entertainment of the mind; But to see all these in their first Seeds, as I may so say; to take in pieces this frame of Nature, and melt it down into its first principles; and then to observe how the Divine Wisdom wrought all these things out of confusion into order, and out of simplicity into that beautiful composition we now see them in; this, methinks, is another kind of joy, which pierceth the mind more deep, and is more satisfactory." Burnet, 54.

[390]Burnet, 115. Cf. similar remarks on p. 189. For the epistemological virtue which William Whewell later emphasized as the "consilience" of a theory, cf. Descartes, 287; Part IV, Article 205: "But those who notice how many things concerning the magnet, fire, and the fabric of the entire World have been deduced here from so few principles (even though they may suppose that I adopted these principles only by chance and without reason), will perhaps still know that it could scarcely have occurred that so many things should be consistent with one another, if they were false."

Yet Burnet's overall approach to the Theory of the Earth transformed Cartesian theorizing, since for Burnet deduction from physical causes yields only a bare idea, not an historical account.[391] Thus Descartes erred, Burnet wrote, and achieved nothing more than a mere hypothesis because of his lack of concordism with antiquities and sacred history:

> An eminent Philosopher of this Age, Monsieur des Cartes, hath made use of the like Hypothesis to explain the irregular form of the present Earth; though he never dream'd of the Deluge, nor thought that first Orb built over the Abysse, to have been any more than a transient crust, and not a real habitable World that lasted for more than sixteen hundred years, as we suppose it to have been.[392]

Going beyond Descartes, Burnet's Theory of the Earth was sacred; that is, not only consistent with biblical history but also explicitly correlated with and constructed by that history. To construct a theory by history is to sanction reasoning from the effects, at least in part. Proving the cause by the effects was at times congenial to Burnet:

> I judg'd it more useful and expedient to lay aside the Causes at present, and begin with the Effects, that we might have some sensible matter to work upon. Bare Idea's of things are lookt upon as *Romantick till Effects* be propos'd, whereof they are to give an account; that makes us value the Causes when necessity puts us upon enquiry after them;....[393]

Burnet offered a *history* as well as a *genesis*, insisting that his method was not that of Descartes because his Theory invoked evidence from sacred history and natural history. On the

[391]The context of a quotation cited above expressed this well: "And though all this hath been deduc'd in due order, and with connexion and consequence of one thing upon another, so far as I know, which is the true evidence of a Theory; yet it may not be sufficient to command the Assent and Belief of some persons, who will allow, it may be, and acknowledge, that this is a fair Idea of a *possible* Deluge in general, and of the destruction of a World by it; but this may be *only an Idea*, they'll say; we desire it may be prov'd from some *collateral arguments, taken either from Sacred History, or from observation, that this hath really been exemplified* upon the Earth, and that Noah's Flood came to pass this way.... what we have deliver'd is more than an Idea...." Burnet, 71. After presenting his account of the Deluge, Burnet concluded "We have now proved our Explication of the Deluge to be more than an Idea, or to be *a true piece of Natural History....*" Burnet, 82; italics added.

[392]Burnet, 93. Burnet's claim to originality in applying Cartesian philosophy to the Deluge should not be taken as wishful thinking; it is too easy for modern historians who know how Burnet read Descartes, to read Descartes' original text in a similar manner. For alternative constructions of Cartesian sacred history see "The Cartesian-Hexameral Birth of the World," beginning on page 541.

[393]Burnet, 134; italics added—the context is the "qualities and conditions of Paradise." Burnet had just acknowledged (p. 134) that "History, both Sacred and Profane, must tell us what they were, and our Theory must show us upon what causes they depended. I had once, I confess, propos'd to my self another method, independent upon History or Effects; I thought to have continued the description of the Primitive or Antediluvian Earth from the contemplation of its causes only...."

one hand, Burnet's Theory retreated where these left off: Because neither sacred history nor natural history provide a sufficient basis for a history of the universe, Burnet declined to offer a cosmogony.[394] On the other hand, Burnet's Theory advanced to discoveries beyond the reach of deduction from physical causes alone, as in his accounts of the ovoid Paradisiacal globe and the timing and effects of the Deluge. Considering the rough form of the globe, Burnet suggested that "the present form of the Earth ... is not deducible from a Chaos, by any known laws of Nature, or by any wit of Man...."[395] At the beginning of his initial presentation of the Deluge, Burnet enjoined the inspection of the rough-formed earth in concert with sacred history in order to determine the physical causes at work:

> And it will be found, it may be, upon a stricter Enquiry, that in the present form and constitution of the Earth, there are certain marks and Indications of its first State; with which if we compare those things that are recorded in Sacred History, concerning the first Chaos, Paradise, and an universal Deluge, we may discover, by the help of those Lights, what the Earth was in its first Original, and what Changes have since succeeded in it.[396]

[394]"But when we speak of a Rising World, and the Contemplation of it, we do not mean this of the Great Universe; for who can describe the Original of that? But we speak of the Sublunary World, This Earth and its dependencies, which rose out of a Chaos about six thousand years ago; . . . ." Burnet, 23. Although Descartes similarly separated the question of the origin of a planet from that of the origin of the universe or even of its vortex, Burnet's Theory was not presented as a logical extension of a comprehensive cosmological system. Thus Roger notes that "Burnet separates the history of the earth from that of the universe, which he thinks to be much older than the earth. In this way, Cartesian general cosmogony becomes merely a theory of the earth. The main reason for not attempting to reconstruct the history of the universe, according to Burnet, is that we have no evidence about this history." Jacques Roger, "Cartesian Model," 103.

[395]Burnet, 227.

[396]Burnet, 27.

The exposition of Burnet's Theory moved from recent effects to prior causes rather than proceeding chronologically according to the causes themselves.[397] More remote causes were established with the help of scripture:

> But to speak the Truth, this Theory is something more than a bare Hypothesis; because we are assur'd that the general ground that we go upon is true, namely, that the Earth rise at first from a Chaos; for besides Reason and Antiquity, Scripture it self doth assure us of that;....[398]

Thus Burnet baptized Cartesian geogony by transforming it into sacred physics and history. This transformation greatly altered the evidential role of natural history and historical evidence in the construction and assessment of Theories of the Earth.[399]

§ 10-iv. Conclusion: Theories of the Earth as Genesis and History

Descartes and Burnet are paradigmatic, representing different epistemic styles for Theories of the Earth. Descartes' genesis, a purely causal Theory, contrasts with Burnet's historical Theory (and the Theories of Steno and Whiston) in which causal outcomes must be corrobo-

[397]Burnet justified his order of topics, explaining why he did not proceed according to a causal sequence: "And though we propose to give a full account of the Origin of the Earth in this Treatise, yet that which we have propos'd particularly for the Title and Subject of it, is to give an account of the primaeval Paradise, and of the universal Deluge: Those being the two most important things that are explain'd by the Theory we propose. And I must beg leave in treating of these two, to change the order, and treat first of the Deluge, and then of Paradise: For though the State of Paradise doth precede that of the Flood in Sacred History, and in the nature of the thing, yet the explication of both will be more sensible, and more effectual, if we begin with the Deluge; there being more Observations and Effects, and those better known to us, that may be refer'd to this, than to the other; and the Deluge being once truly explain'd, we shall from thence know the form and Quality of the Ante-diluvian Earth." Burnet, 27.

[398]Burnet, 116. Cf. "And it will never be beaten out of my head, but that St. Peter hath made the same distinction sixteen hundred years since, and to the very same purpose; so that we have sure footing here again, and the Theory riseth above the character of a bare Hypothesis. And whereas an Hypothesis that is clear and proportion'd to Nature in every respect, is accounted morally certain, we must in equity give more than a moral certitude to this Theory," Burnet, 117. Burnet qualified the latter statement: "But I mean this only as to the general parts of it; for as to particularities, I look upon them as only problematical, and accordingly I affirm nothing therein but with a power of revocation...."

[399]This analysis corroborates the point made by Roger that with Burnet there was "clearly a shift from the Cartesian model and from its most typical features, from a distinctly deductive science to a more empirical and historical type of knowledge. In this view of the problem, theoretical questions become historical ones, and factual answers are given by the Bible." Roger goes so far as to say that this transformation of the Cartesian Theory was a "brilliant misinterpretation." Jacques Roger, "Cartesian Model," 103, 112.

rated by empirical evidence whether from antiquities, scripture, or natural history. Though Burnet regarded Descartes' method as speculative (just as Burnet's critics regarded his Theory as a fictional romance), Descartes and Burnet each regarded his own method as reliable and epistemically superior, the method most suited to discovering a true portrait of the Earth and its past. Moreover, the divergent epistemic styles of Descartes and Burnet found expression in the contrasting rhetorical styles of their figures and illustrations.

We have shown exactly how Burnet's geogonic series of global sections was beholden to Descartes yet, clearly, other aspects of Burnet's Theory departed considerably from Descartes. We have seen that, taken as a whole, Burnet's didactic and evidential uses of visual representation were no more a crude imitation of Descartes than was Descartes' didactic use of cosmogonic sections a crude imitation of Robert Fludd. A close reading of Burnet's frontispiece and its associated illustrations has shown that Burnet transformed a Cartesian geogonic series into a comprehensive visual rhetoric which drew upon apocalyptic visions of history and evidence from classical antiquities, and linked diverse forms of visual witnesses in a powerful and integrated combination. Abstract global sections for didactic instruction were combined with elegant global views for evidential historical reconstruction and ornamental, mythopoeic self-authentication. His visual rhetoric did not rest in contemplation of first causes, but moved particularly and mythopoeically—away from the causes toward the natural and historical effects, and away from the abstract toward the imagined experience of the actual concrete thing. Because of the repeated conjunction of global sections with global views, a reader is trained to regard even the more abstract sections as representing the concrete reality of the Earth in a given historical moment. The global views, both global and regional, render the sections more plausible, indicating that their features accurately correspond to a real body which actually exists, not a possibly false genetic idea. Yet where even global views fail to convey the impression of immediate physical reality, Burnet deployed them in association with strong verbal calls for a level of physical modelling that was neither technically achievable nor textually distributable. The verbal descriptions of the rough physical model of the globe amounted to the creation of an "imaginary visual witness" in order to convey with greater immediacy the physical reality of the brokenness of the actual Earth. For Burnet, the causes of the present form of the Earth are neither discovered nor conveyed apart from their actual and real effects. Burnet's mythopoeic visual strategy amounts to a transformation of the Cartesian visual elements rather than simple imitation, and reflects a transformation of Theories of the Earth from genesis into history.

CHAPTER 6 Technical Naturalization: Portraits of a Dynamic Tradition

§ 1. Introduction

In the last chapter we traced the establishment of a dialectical tradition of inquiry and debate by surveying global illustrations, which provide a representative, holistic sample of what seventeenth-century Theories of the Earth were about.[1] Our interpretation did not begin with observer categories stipulating the nature of "historical sensibility" nor with a disembodied definition of a "Theory of the Earth." Rather, the works themselves were inspected in an effort to constrain interpretation by actors' categories—in this case, as they were visually expressed and, as it turned out, with particular attention to hexameral idiom. Without implying that hexameral idiom was the only or the most significant or even a ubiquitous characteristic of Theories of the Earth, con-

[1] The methodological rationale for sketching a portrait of the tradition on the basis of its visual representations is given in "Self-Portrait of the Tradition," beginning on page 397.

tested interpretations of the biblical account of the third day of creation appeared from the illustrations as one of many important contexts which shaped the establishment of the tradition. By affecting the ways many Theorists developed empirical evidence, the appropriation of hexameral idiom undermines conventional characterizations of Theories of the Earth as deductive, completely causal, general theories which took no regard of contingent events. Hexameral idiom provided Theorists with an organizing framework for assimilating and disseminating histories of successive events in the Earth's past based on a variety of kinds of empirical evidence.

In this chapter on the basis of additional snapshots of global sections and views, more briefly considered, we sketch a portrait of a dynamic tradition and its technical transformations through the late eighteenth century.[2] The emerging picture displays a panorama of perspectives—cyclic, steady-state, genetic, and incipiently historical—offered by Theories of the Earth regarding the formation and history of the Earth. From the initial establishment of the tradition in the Burnet controversy, Theories of the Earth continued to be sustained as a textual tradition by a diversification of appropriated technical contexts. For this reason, in order to provide a representative overview or sketch of the tradition, this chapter is roughly organized around the kinds of phenomena emphasized by the global representations (e.g., magnetism, mining, fossils, strata) or the incipient technical research programs developed to investigate such phenomena (e.g., geognosy). Because of the diversification of appropriated technical contexts in a dynamic tradition, no single characteristic can be fully representative of the tradition as a whole—including global illustrations and hexameral idiom. An increasing number of important Theories did not include global sections or views and are not considered here. However, global illustrations still commonly appear and they suggest something important about the variety of the tradition. One purpose of this chapter is to emphasize that vari-

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2 See the discussion of the transformation of textual traditions in "Appropriation Model: An Alternative to Marginality," beginning on page 341.

ety. No attempt has been made to be exhaustive in scope or coverage, either to include every global representation or to discuss any global illustration in detail, as in the previous chapter, although the images of a few authors are selected for more careful description. Similarly, hexameral idiom is of irregular prominence in these illustrations, although it often remained important in ways that will be assessed in the Epilogue.

§ 2. Magnetic Theories of the Earth

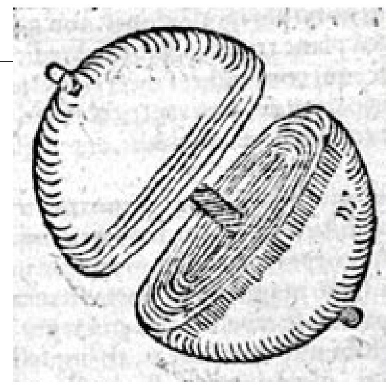

FIGURE 189. Kepler, *Epitome of Copernican Astronomy*, p. 121. The Earth as a spinning top.

Description. Book I, Principles of the Doctrine of the Sphere, part 5: On the diurnal motion of the Earth. A physical axis in the heavens is no more necessary for a rotating Earth than for a spinning top.[3]

As late as the nineteenth century Johannes Kepler was retrospectively regarded as a Theorist of the Earth, particularly as a founder of Theories which emphasized macrocosm-microcosm analogies between the Earth and the human body or those which were based on explanations of magnetic phenomena. Cuvier described one recent system as an extravagant attempt to rehabilitate a vitalistic Keplerian Theory.[4] About the same time in Philadelphia Abraham Rees described Theories of the Earth that attended to the layers or shells of the Earth, perhaps inferred from magnetic phenomena, as originating with Kepler and Edmond Halley.[5] As with any "founder tale" such retrospective attributions need to be examined critically for Whiggish distortions, and interpreted as rhetorically significant for what they reveal about the later context of attribution.[6] The development of six-

3 Kepler, *Epitome*, 120-121: "Proba de facultate corporea?" "...species motus, quo Deus Creator globum Telluris primum incitavit, arctius & durabilius in terræ sese corpus insinuaverit, inque fibrarum circularitatem, & veluti in formam corpoream specialem concesserit, non jam hospes amplius in Terra, ut illa in Turbine, sed inquilina planè, seu materiæ suæ victrix & domitrix existens."

teenth-century theories of the Earth has yet to be written.[7] Although Kepler did not have the luxury of contributing to an established textual tradition devoted to contesting interdisciplinary perspectives of the Earth, yet he did theorize about the Earth on a number of occasions. It is adequate in the present discussion simply to note that Kepler's views were appropriated by some later readers. In the *Epitome of Copernican Astronomy* (1618) Kepler discussed the possiblity (to which Abraham Rees alluded) that the Earth consists of layers of concentric fibers.[8] Kepler's argument in the same work that the tilt of the Earth's axis was providentially arranged for the sake of animal life was widely cited against the untilted paradisiacal globe of Milton, Burnet and Whiston.[9] His physical astronomy added prestige, if that were possible, to William Gilbert's investigations of magnetism. Kepler remained interested in meteorology all his life, and frequently invoked macrocosm-microcosm metaphors in describing meteoro-

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4 Georges Cuvier, *Essay on the Theory of the Earth* (Edinburgh and London, 1817), 44–45: "Other writers have preferred the ideas of Kepler, and, like that great astronomer, have considered the globe itself as possessed of living faculties. According to them, it contains a circulating vital fluid. A process of assimilation goes on in it as well as in animated bodies. Every particle of it is alive. It possesses instinct and volition even to the most elementary of its molecules, which attract and repel each other according to sympathies and antipathies. Each kind of mineral substance is capable of converting immense masses of matter into its own peculiar nature, as we convert our aliment into flesh and blood. The mountains are the respiratory organs of the globe, and the schists its organs of secretion. By the latter it decomposes the waters of the sea in order to produce volcanic eruptions. The veins in strata are caries, or abscesses [sic] of the mineral kingdom, and the metals are products of rottenness and disease, to which it is owing that almost all of them have so bad a smell.*" Note: "*M. Patrin has used much ingenuity to establish this view of the subject, in several articles of the *Nouveau Dictionnaire d'Histoire Naturelle*." On Cuvier's characterization of Patrin's Theory as extreme and extravagant see footnote 89 on page 311.

5 "Kepler, in his *Epitom. Astron. Copern*., and after him Dr. Halley, in his Inquiry into the Causes of the Variation of the Needle, *Phil Trans*. N° 195, suppose our earth may be composed of several crusts or shells, one within another, and concentric to each other. If this be the case, it is possible the ring of Saturn may be the fragment or remaining ruin of his former exterior shell, the rest of which is broken or fallen down upon the body of the planet." Abraham Rees, *The Cyclopaedia; or, Universal Dictionary of Arts, Sciences, and Literature*, First American Edition, 41 vols. (Philadelphia: Published by Samuel F. Bradford, and Murray, Fairman and Co, 1810–1842), Volume 31, s.v. "Ring, Astronomy," no page number.

6 Cf. the discussion of Bourguet's list of sixteenth-century founders of the Theories of the Earth tradition in Chapter 1, and the discussion of geologists' retrospective attribution of Hutton as the founder of geology in Chapter 3. Cf. Brannigan's analysis of the importance of later attribution, or recognition, as an important aspect completing the process of scientific discovery; Augustine Brannigan, *The Social Basis of Scientific Discovery* (Cambridge: Cambridge University Press, 1981).

7 A preliminary survey is Sister Mary Suzanne Kelly, "Theories of the Earth in Renaissance Cosmologies," in *Toward a History of Geology*, ed. Cecil J. Schneer (Cambridge: MIT Press, 1969), 214–225. More recently see Rienk Vermij, "Subterranean Fire: Changing Theories of the Earth during the Renaissance," *Early Science and Medicine* 3 (1998): 323–347.

8 Johannes Kepler, *Epitome Astronomiæ Copernicanæ, Usitatâ formâ Quæstionum & Responsionum conscripta, inq; VII. Libros digesta, quorum Tres hi priores sunt de Doctrina Sphæricâ*, 2 vols. (Lentijs ad Danubium, excudebat Johannes Plancus, 1618).

logical phenomena. In *Harmonices mundi* (1619) he attributed a sentient faculty to the Earth in order to explain the correlation of astronomical events with weather patterns.[10] Schneer has discussed the relevance of Kepler's *Strena* (1611) to the study of crystallization,[11] and we have noted Kepler's thought-experiment in the *Somnium* (1634) describing the Earth as seen from the Moon.[12] Finally, in the preface to the *Astronomia nova* (1608), Kepler deployed the traditional hermeneutical principle of accommodation to defend against scriptural objections to the motion of the Earth; this clearly-written and penetrating analysis (soon translated into

[9] For example, in chapter 4 of the *Examination*, John Keill cited Kepler's *Epitome*, Bk. III, Part 4, to remind his readers that Kepler showed the advantages of the present obliquity of the earth's axis to the axis of the ecliptic. Rather than a universal perpetual spring, Keill countered, if the axis of the Earth really were parallel with the axis of the ecliptic, the Earth would be subjected to some of the worst possible conditions. As Kepler argued, the Earth was designed to be a place of generation and corruption, and the alterations of the seasons serve this purpose. "God hath chosen better for us than we could have done for ourselves." Rather than a perpetual spring, experienced all over the globe, the actual consequences of an untilted globe would be a perpetual twilight at the poles, an eternal winter with the Sun always moving along the edge of the horizon. At the equator, a perpetual summer, with the Sun directly overhead at noon. No changing of the seasons. The Earth would be uninhabitable over great areas, including England, and even the temperate zones would be very narrow. Keill concluded with a warning that final causes and quantitative arguments are more valid than mechanical hypotheses: "This [the mathematical demonstration of greater warmth] shews us also how much we ought to regard final causes in *Natural Philosophy*, which in things of this nature are by far more certain and convincing than any of the *Physical* and *Mechanical* ones which the Theorist brings to prove the truth of his assertion... it being just that God Almighty should deliver these men up to follow strange delusions, who neglecting to proceed upon final causes the true principles of *Natural Philosophy*, and to square their notions according to the Divine Revelations contained in Holy Scripture have followed the wild and extravagant fancies of their own imaginations." John Keill, *An Examination of Dr. Burnet's Theory of the Earth, Together with some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford: Printed at the Theater, 1698), 62–83.

[10] "In fact, the globe of the Earth will be a body such as that of some animate being, and what its soul is to an animate being, that the sublunary nature which we seek, which sets the weather in motion at the appearance of aspects, will be to the Earth." Johannes Kepler, *The Harmony of the World*, trans. E. J. Aiton, A. M. Duncan and J. V. Field (Philadelphia: American Philosophical Society, 1997), 363; cf. Johannes Kepler, *Harmonices mundi libri V* (Linz: Sumptibus Godofredi Tampachii; Excudebat Ioannes Plancus, 1619), 160. Kepler continues with a macrocosm-microcosm analogy (363–364): "As this analogy succeeded, the result was that I pursued it further, comparing the bodies of animate beings with the body of the Earth as well. I saw that all the many things which come from the body of an animate being and testify that there is a soul in it, also come from the body of the Earth. For as the body puts out hairs on the surface of its skin, so the Earth puts out plants and trees; and lice are born on them in the former case, caterpillars, cicadas, and various insects and sea monsters in the latter. And as the body displays tears, mucus, and earwax, and also in places lymph from pustules on the face, so the Earth displays amber and bitumen; as the bladder pours out urine, so the mountains pour out rivers; as the body produces excrement of sulphurous odor and farts which can even be set on fire, so the Earth produces sulphur, subterranean fires, thunder, and lightning; and as blood is generated in the veins of an animate being, and with it sweat, which is thrust outside the body, so in the veins of the Earth are generated metals and fossils, and rainy vapor." Kepler's soul of the Earth comprehends the geometrical harmonies of the heavens as well as the ideas of created things in order to bind them together in sympathy, and this high status seems consistent with Kepler's assertion that (p. 372) "Whatever has been said up to this point about the soul of the Earth can also be applied similarly to the faculties of the human soul." Caspar notes that Kepler's meteorological writings were consistent with these views, but one must be careful to qualify Caspar's suggestion that Kepler's animistic perspective was at odds with his mechanical philosophy, just as the tension between mechanical philosophy and the soul in Gilbert's magnetic philosophy may be overstated. Max Caspar, *Kepler*, trans. and ed. C. Doris Hellman (New York: Dover, 1993), 45, 86, 281.

English) became an important resource for Theorists who interpreted the hexameral account as reporting how the phenomena appeared from the perspective of an Earth-bound observer (a common assumption of literal day-age interpretations through the nineteenth century).[13]

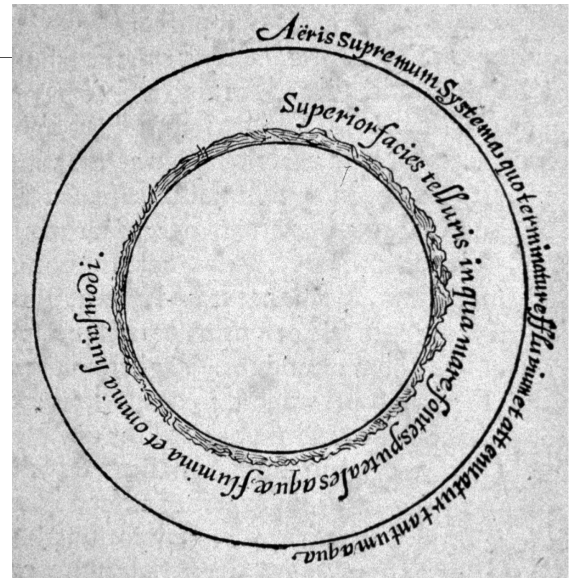

FIGURE 190. William Gilbert, *De mundo* (1651). HSCI. Partial meteorological section.

As we have noted, the last book of William Gilbert's *De magnete* (1600) was devoted to outlining a magnetic cosmology which was expanded in the first two books of *De mundo*.[14] Bennett comments on the significance of Gilbert's work:

> The magnetical and mechanical philosophies interacted in England throughout the seventeenth century, and were not mutually exclusive. For Englishmen such as Wren it was Gilbert and Harvey, not Descartes or even Bacon, who represented the new experimental philosophy. As a consequence of the magnetical philosophy, English mechanical philosophers worked with a much less restrictive definition of material action than their counterparts on the continent, e.g., entertaining such concepts as attractive forces and spheres of activity.[15]

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[11] Johannes Kepler, Strena seu de niue sexangula (Francofvrti ad Moenvm: Apud G. Tampach, 1611); cf. Cecil J. Schneer, "Aspects of Form and Structure: The Renaissance Background to Crystallography," in *The Analytic Spirit: Essays in the History of Science in Honor of Henry Guerlac*, ed. Harry Woolf, 279–292 (Ithaca: Cornell University Press, 1981).

[12] See footnote 122 on page 490.

[13] Johannes Kepler, *Johannes Kepler's New Astronomy*, trans. William H. Donahue (Cambridge: Cambridge University Press, 1992).

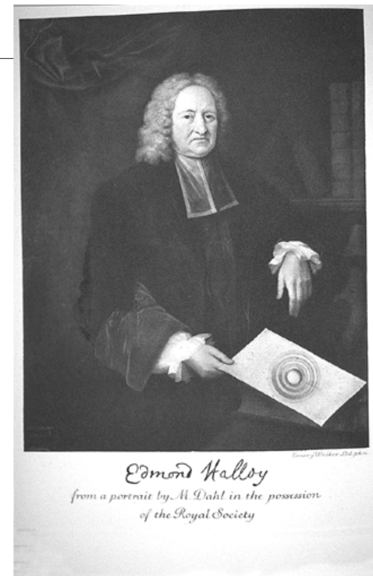
[14] Gilbert held (like Digges) that the meteorological regions are held to the Earth by magnetism and that the stars are of varying distances from the Earth. The planets move around the Sun through a void, surrounded by their effluvia, from the initial impulse given them at their creation. The effluvia of the Earth all derive from one common magnetic, earthy element. Mary Suzanne Kelly, "The *De Mundo* of William Gilbert" (Ph.D. dissertation, University of Oklahoma, 1961). Cf. William Gilbert, *De Mundo nostro Sublunari Philosophia Nova. Opus posthumum, Ab Authoris fratre collectum pridem & dispositum, nvnc Ex duobus MSS. codicibus editum*, ed. Gvilielmi Boswelli (Amstelodami: Apud Ludovicum Elzevirium, 1651).

[15] J. A. Bennett, "Cosmology and the Magnetical Philosophy, 1640-1680," *Journal for the History of Astronomy* 12 (1981): 165–177.

Seventeenth-century magnetic philosophers stimulated by Gilbert's ideas include Francis Bacon, Athanasius Kircher, H. Gellibrand, and Robert Hooke.[16] Among the most important for Theories of the Earth was Edmond Halley.

FIGURE 191. Edmond Halley, portrait.

Caption. "We have adventured to make the Earth hollow and to place another Globe within it..." Halley, "Magnetical Needle," 572.



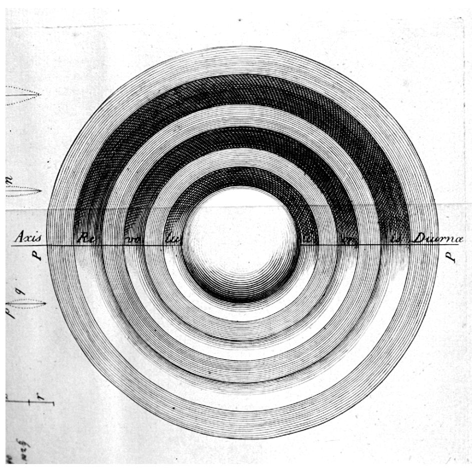


FIGURE 192. Halley, "Magnetical Needle" (1691). Global section.

Caption. *p.p*: Common axis. Thickness of outer shell: 500 miles. Outer cavity: 500 miles. Venus-sized shell: 500 miles. Middle cavity: 500 miles. Mars-sized shell: 500 miles. Inner cavity: 500 miles. Mercury-sized solid core: 2,000 miles diameter.

Description. "Lastly, To explain yet farther what I mean, I have adventured to adjoyn the following Scheme, wherein the Earth is represented by the outward Circle, and the three inward Circles are made nearly proportionable to the Magnitudes of the Planets Venus, Mars and Mercury, all which may be included within this Globe of Earth, and all the Arches more than sufficiently strong to bear their weight." Halley, "Magnetical Needle," 576.

[16] Aspects of seventeenth-century magnetical philosophies are surveyed by J. A. Bennett, "Cosmology and the Magnetical Philosophy, 1640-1680," *Journal for the History of Astronomy* 12 (1981): 165–177; Gregory A. Good, "Follow the Needle: Seeking the Magnetic Poles," *Earth Sciences History* 10 (1991): 154–167; and Martha R. Baldwin, "Magnetism and the Anti-Copernican Polemic," *Journal for the History of Astronomy* 16 (1985): 155–174; and Sister Mary Suzanne Kelly, "The *De Mundo* of William Gilbert" (Ph.D. dissertation, University of Oklahoma, 1961). Illustrative is Rees argument that Francis Bacon "philosophized freely as a speculative system builder.... It should be allowed that Bacon was as much impressed by Gilbert's cosmological speculations as by the experimentalism inextricably bound up with them. Certainly he took Gilbert to task for erecting an entire philosophy on magnetic experiments but, as Kelly has pointed out, he actually adopted one of Gilbert's theoretical innovations—the idea of the 'orb of virtue' which Gilbert had derived from Porta and generalized at the cosmic level. We now know that Bacon also took Gilbert's verticity theory seriously." Graham Rees, "Francis Bacon on Verticity and the Bowels of the Earth," *Ambix* 26 (1979): 208.

On the basis of the changing direction of magnetic north (which he was able to document from decades of observations), Edmond Halley suggested that a magnetic core rotates within the Earth independently of the outer crust. To depict this explanation in the *Philosophical Transactions* he published a beautiful plate of hollow shells within the Earth (Figure 192), and years later, chose the same drawing to be included in his portrait (Figure 191).[17] Halley acknowledged that a movable magnetic body within the Earth might shift its center of gravity and "produce very wonderful Effects," but he proposed that the internal layers (however many might prove necessary given future observations) are concentric with the crust.[18] All concentric parts turn each day around slightly different axes, with the

[17] Edmond Halley, "An Account of the cause of the Change of the Variation of the Magnetical Needle; with an Hypothesis of the Structure of the Internal parts of the Earth: as it was proposed to the Royal Society in one of their late meetings," *Philosophical Transactions of the Royal Society of London* 16 (1691): 563–578. In an earlier paper (published in the *Philosophical Transactions* number 148) Halley had proposed that the Earth has four magnetic poles, a pair near each pole of the equator, and that the nearest pole to any location on Earth determined the variation of the magnetic needle in that area. Other articles by Halley pertaining to Theories of the Earth are Edmund Halley, "An Estimate of the Quantity of Vapour raised out of the Sea by the warmth of the Sun; derived from an Experiment shewn before the R. Society at one of their late Meetings," *Philosophical Transactions of the Royal Society of London* 16 (1687): 366-370; Edmond Halley, "An Account of the Circulation of the Watry Vapors of the Sea; and of the Cause of Springs," *Philosophical Transactions of the Royal Society of London* 16 (1691): 468–473; Edmond Halley, "Some Considerations about the Cause of the universal Deluge, laid before the Royal Society, on the 12th of December 1694," *Philosophical Transactions of the Royal Society of London* 33 (1724): 118–123; Edmond Halley, "Some farther Thoughts upon the same Subject, delivered on the 19th of the same Month," *Philosophical Transactions of the Royal Society of London* 33 (1724): 123–124; and [Edmond Halley], "An Account of some Observations lately made at Nurenburg by Mr. P. Wurtzelbaur, shewing that the Latitude of that Place has continued without sensible alteration for 100 Years last past; as likewise the Obliquity of the Ecliptick; by comparing them with what was observed by Bernard Walther in the Year 1487," *Philosophical Transactions of the Royal Society of London* 16 (1678): 403–406. The first two essays were presented as a step toward a "real and Philosophical Meteorology" by means of quantitative arguments that (contra Kircher and others) water vapor is the only source not only of rain but also of springs and fountains. The two 1724 essays discussed (with friendly correction of Hooke) the effects of past cometary impacts including the tilting of the axis of the Earth and the inundating of the continents by means of oscillating tidal waves. The second 1724 essay reassigned the inundations after the cometary impact to the creation week instead of the deluge; a notice to the reader inserted immediately afterward in the posthumously published volume claimed priority for Halley against Whiston (p. 125): "Here the Reader is desired to observe, that Mr. William Whiston's Book, entituled, *A New Theory of the Earth,* was not published till about a Year and a half after the Date hereof, and was not presented before June 24, 1696. to the Royal Society." For a biography see Sir Alan H. Cook, *Edmond Halley: Charting the Heavens and the Seas* (Oxford: Clarendon Press, 1998).

[18] "Now considering the structure of our Terraqueous Globe, it cannot be well supposed that a very great part thereof can move within it, without notably changing its Centre of Gravity and the Equilibre of its parts, which would produce very wonderful Effects in changing the Axis of Diurnal Rotation, and occasion strange alteration in the Sea's Surface, by Inundations and Recesses thereof, such as History never yet mentioned. Besides, the solid parts of the Earth are not to be granted permeable by any other than fluid Substances, of which we know none that are any ways Magnetical. So that the only way to render this Motion intelligible and possible, is, to suppose it to turn about the Centre of the Globe, having its Centre of Gravity fixt and immoveable in the same common Centre of the Earth: And there is yet required that this moving internal Substance be loose and detached from the external parts of the Earth, whereon we live; for otherwise were it affix'd thereto, the whole must necessarily move together." Halley, "Magnetical Needle," 567–568.

outer crust perhaps falling behind or running ahead by "a very minute difference in length of time, by many repetitions becoming sensible."[19] Perhaps the initial impetus to the eastward rotation of the Earth was given on the external shell only, and thus the internal shells lag slightly behind.

Halley corroborated his hypothesis by answering several anticipated objections. First, in response to the criticism "that there is no Instance in Nature of the like thing..." Halley pointed to Saturn and its ring. "If this Ring were turned on one of its Diameters, it would then describe such a concave Sphere as I suppose our External one to be." The fact that Saturn does not collide or knock into its ring answers the objection that the middle globe "would not keep its place in the Centre, but be apt to deviate therefrom, and might possibly chock against the concave Shell, to the ruine or at least endammaging thereof." The concentric bodies share a common center of gravity. Another objection might be "that the water of the Sea would perpetually leak through, unless we suppose the cavity full of water," yet Halley argued that by the wisdom of the Creator the globe is made for a lasting habitation. Perhaps water percolating down through the outer shell combines with subterranean particles and coagulates into stone, fortifying the shell. Nor are the inner bodies without their own uses, for they may be other worlds and support intelligent beings:

> But since it is now taken for granted that the Earth is one of the Planets, and they all are with reason supposed Habitable, though we are not able to define by what sort of Animals; and since we see all the parts of the Creation abound with Animate Beings, as the Air with Birds and Flies, the Water with the numerous variet-

[19] "So then the External Parts of the Globe may well be reckoned as the Shell, and the Internal as a Nucleus or inner Globe included within ours, with a fluid medium between. Which having the same common Centre and Axis of diurnal Rotation, may turn about with our Earth each 24 hours; only this outer Sphere having its turbinating Motion some small matter either swifter or slower than the internal Ball. And a very minute difference in length of time, by many repetitions becoming sensible; the Internal parts will by degrees recede from the External, and not keeping pace with one another will appear gradually to move either Eastwards or Westwards by the difference of their Motions." Halley continued: "Now supposing such an Internal Sphere having such a Motion, we shall solve the two great difficulties we encountred in my former Hypothesis. For if this exterior Shell of Earth be a Magnet having its Poles at a distance from the Poles of Diurnal Rotation; and if the Internal Nucleus be likewise a Magnet, having its Poles in two other places distant also from the Axis; and these latter by a gradual and slow Motion change their place in respect of the External; we may then give a reasonable account of the four Magnetical Poles I presume to have demonstrated in No. 148 of these Transactions; as likewise of the changes of the Needles Variations, which till now hath been unattempted." Halley, "Magnetical Needle," 568.

> ies of Fish, and the very Earth with Reptiles of so many sorts; all whose ways of living would be to us incredible did not daily Experience teach us. Why then should we think it strange that the prodigious Mass of Matter, whereof this Globe does consist, should be capable of some other improvement than barely to serve to support its Surface? Why may not we rather suppose that the exceeding small quantity of solid Matter in respect of the fluid Ether, is so disposed by the Almighty Wisdom as to yield as great a Surface for the use of living Creatures as can consist with the conveniency and security of the whole. We ourselves, in Cities where we are pressed for room, commonly build many Stories one over the other, and thereby accommodate a much greater multitude of Inhabitants.[20]

Nor are the cavities necessarily dark; the concave surfaces may glow, or they may have their own luminaries or other light sources unknown to us.

For corroboration Halley cited Newton's calculations of the Moon's effect on the tides which implied that the Moon is more solid than the Earth by a ratio of nine to five. Assuming that the Earth and Moon are composed of the same materials, then this figure implies that four-ninths of the Earth's volume, between the internal spheres, must be air. Halley noted that the lower specific gravity of the Earth might be necessary to preserve the stability of the Earth and Moon system; if the Earth were solid it would push more quickly through the ether and leave the Moon behind. In any case, Halley proposed his Theory as a provisional hypothesis; rigorous calculations would have to wait for minute discrepancies to become evident:

> the nice Determination of this and of several other particulars in the Magnetick System is reserved for remote Posterity; all that we can hope to do is to leave behind us Observations that may be confided in, and to propose Hypotheses which after Ages may examine, amend or refute.[21]

Some of the eighteenth-century Theories of the Earth which continued to update Halley's hollow-Earth magnetic Theory are discussed in Chapter 2.[22] There were many others not examined here, such as the remarkable Theory of Henri Gautier (1660–1737), a French engineer who envisioned a fluid atmosphere on both sides of the external crust.[23]

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[20] Halley, "Magnetical Needle," 575.

[21] Halley, "Magnetical Needle," 571.

[22] See "Case 2: Earth's Center of Gravity," beginning on page 237.

Magnetic and hollow-Earth theories continued with nineteenth-century calls for polar expeditions.[24] *Symzonia* (1820), by John Cleves Symmes, is a novel about a captain Adam Seaborn who finds entrances to the interior worlds at the poles. James McBride defended this theory with his *Symmes's Theory of Concentric Spheres* (1826), which articulated a nationalist inspiration for an American expedition: If Symmes' theory were true, McBride argued, America should be the country to discover it. If false, the polar regions remain worthy of exploration in their own right, which might result in the discovery of a northwest passage. With nineteenth-century hollow-Earthers, Theories of the Earth began a transition into folk science like that into scriptural geology discussed in Chapter 1. Like scriptural geology, hollow-Earth theories had a wide appeal. Edgar Allen Poe was sympathetic to Symmes' views, as was Jules Verne. Jules Verne's *Journey to the Center of the Earth* (1864) and *The Adventures of Captain Hatteras* (1866) both envisioned hollow globes. In the latter Captain Hatteras discovers the north pole and hints at access to lands within a hollow Earth through a volcano.

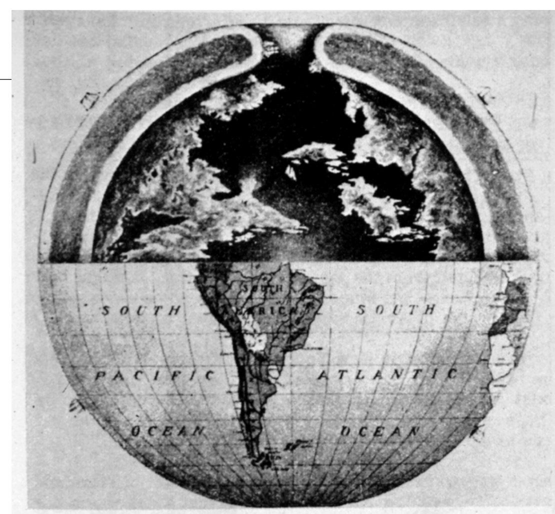

FIGURE 193. William Reed, *Phantom of the Poles* (New York: Walter S. Rockey Company, 1906). Global hemisection and global view.

Caption. "The earth is hollow. The poles so long sought are but phantoms. There are openings at the northern and southern extremities. In the interior are vast continents, oceans, mountains and rivers. Vegetable and animal life are evident in this new world, and it is probably peopled by races yet unknown to the dwellers upon the earth's exterior."

By the twentieth century the hollow-Earth, expeditionary science of the nineteenth

[23] Gautier's text is discussed and reprinted in François Ellenberger, "À l'Aube de la Géologie Moderne: Henri Gautier (1660–1737)," *Histoire et Nature: Cahiers de l'Association pour l'histoire des Sciences de la Nature* 7, 9–10 (1975,1976, 1977).

[24] For information on nineteenth- and twentieth-century hollow-Earthers in this and the following paragraph I am indebted to William Marion Miller, "The Theory of Concentric Spheres," *Isis* 33 (1941): 507–514; Conway Zirkle, "The Theory of Concentric Spheres: Edmund Halley, Cotton Mather, and John Cleves Symmes," *Isis* 37 (1947): 155–159; and Edna Kenton, *The Book of Earths* (New York: William Morrow & Company, 1928).

century completed its transition into a remarkably persistent folk science, including Cyrus Reed Teed, *Cellular Cosmogony* (1898), William Reed, *The Phantom of the Poles* (1906), and Marshall B. Gardner, *A Journey to the Earth's Interior* (1920). William Reed displays the logical skills of this genre: "The earth is either hollow or it is not. What proof have we that it is not hollow? None at all that is positive and circumstantial. On the contrary, everything points to its being hollow." In a more recent version, Raymond Bernard, a physician, argues that a huge underground world provides the home of a super-race which left us alone until we threatened their existence with atom bombs. Now they continually monitor our actions with flying saucers launched through the polar openings.[25] To reaffirm what was argued in the first chapter, however, it is no more legitimate to blame Halley or the textual tradition of Theories of the Earth for these latter-day vestiges than it is to credit Halley and Theories of the Earth as precursors of recent scientific discoveries of the Earth's rotating magnetic core.[26]

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[25] Raymond Bernard, *The Hollow Earth* (New York: Fieldcrest Publishing Company, 1964). The quotation from Reed (p. 282) is cited by Bernard, 96.

[26] A similar point is made with respect to creationism and Theories of the Earth in "Natural Knowledge and Textual Traditions," beginning on page 66, and with respect to Whiston and Velikovsky in Chapter 3 (see comment by Secord in footnote 72 on page 301). On the transformation of textual traditions into technical scientific fields and folk-science textual traditions see "Textual versus Technical Traditions," beginning on page 79. A team of Harvard and Berkeley geophysicists argue, employing numerous technical global sections, that "the inner core of the Earth... discovered 60 years ago" rotates about three degrees per year faster than the mantle; Wei-jia Su, Adam M. Dziewonski and Raymond Jeanloz, "Planet Within a Planet: Rotation of the Inner Core of Earth," *Science* 274 (1996): 1883-1887.

§ 3. Mosaic Theories: Fossil Emplacement by Diluvial Dissolution

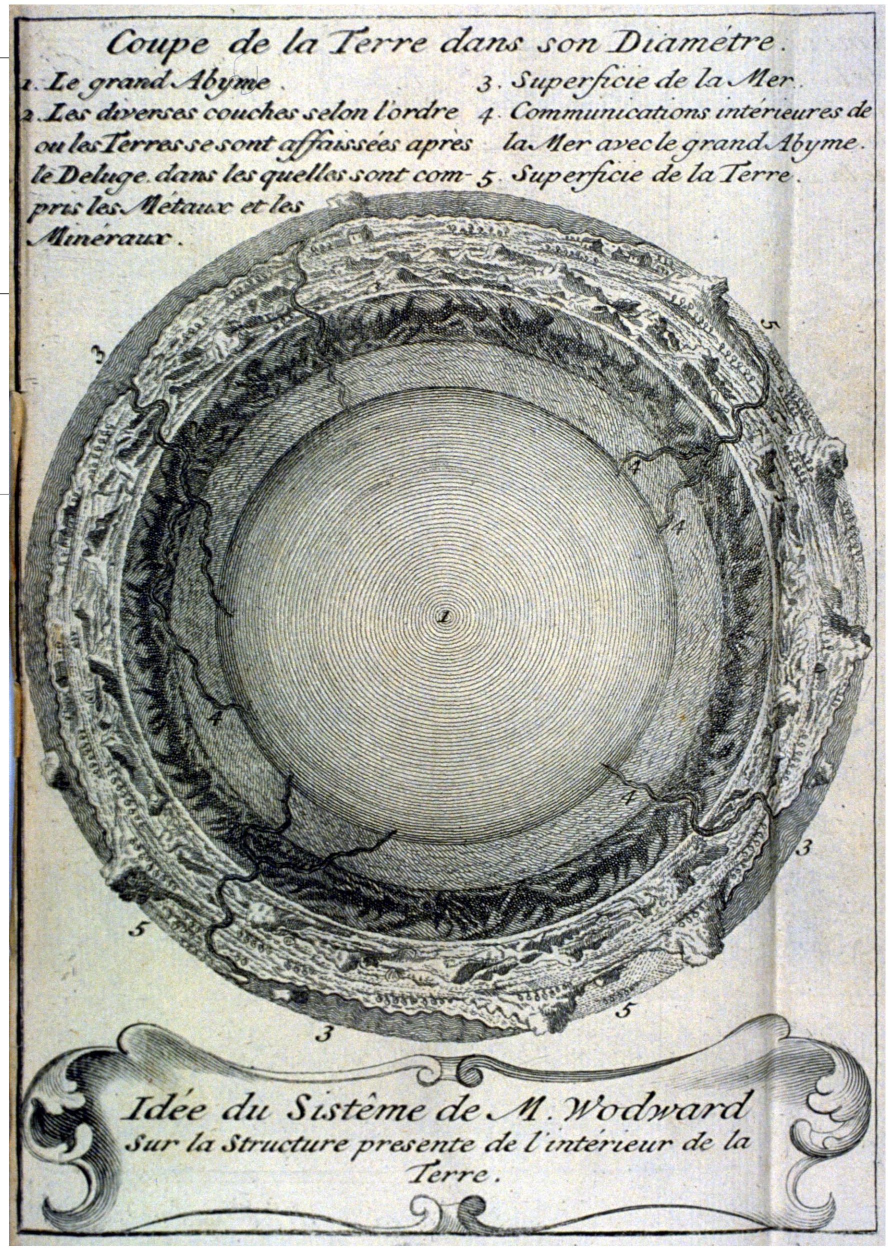

FIGURE 194. John Woodward, *Geographie Physique* (Amsterdam and Paris, 1735). Global section. LH.

Caption. "Idée du Sistême de M. Woodward sur la Structure presente de l'intérieur de la Terre."

Description. 1: The great, central watery abyss. 2: Diverse layers of the Earth, many containing fossils, minerals and metals, sorted according to their specific gravities. 3: Oceans. 4: Passages between the seas and the central abyss. 5: Continents.

John Woodward's *Natural History of the Earth* (1695) shows that the Aristotelian solid earth, magnetic shells, and the fire of the volcanists, alchemists, mineralogists or miners were not the only ways of thinking about the Earth's interior. As the occurrence of "natural history" in the title suggests, Woodward's Theory of the Earth was based on the evidence of extraneous fossils which he collected and solicited from world travelers.[27] Woodward began by repeating the arguments of Steno that fossils derive from once-living organic bodies rather than as sports of nature growing like crystals within the rocks. Accepting Newton's phenomenalist explanation of gravity as the preternatural effect of the action of divine will, Woodward supposed that at the onset of the deluge God merely withheld his usual mode of action, which caused the Earth to dissolve into its original chaos. Without gravitational attraction to maintain cohesion, all physical objects were dissipated within the homogenous mixture except for organic bodies, which held together because of their fibrous internal structure. As the deluge came to an end the chaos gradually sorted out to form layers of different specific gravity, an idea which he argued explains the distribution of fossils as artifacts of the deluge within the regular order of the strata. In seeming contradiction to his rule of specific gravity, Woodward appropriated the Platonic theory of a great watery abyss within the Earth, into which he had the flood waters recede (Figure 194). Woodward was immediately accused of plagiarizing Steno's arguments on fossils and confronted with reports of strata which were not ordered according to their specific gravities.[28] Despite Newton's similar, phenomenalist understanding of gravity at this time and Woodward's emphasis on the empirical evidence of fossils, it is perhaps because of the prominence of Woodwardian Theories that the tradition of Theories of the Earth is characterized as appealing to supernatural causes and (like the Theories of Strachey and Smith considered below) constrained by a steady-state temporal sensibility.[29] Despite his antiquarian avocation, Woodward's explanation of the deluge envisioned a stable,

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[27] John Woodward, *An Essay toward a Natural History of the Earth: and Terrestrial Bodies, Especially Minerals: As also of the Sea, Rivers, and Springs. With an Account of the Universal Deluge: And of the Effects that it had upon the Earth* (London: Printed for Ric. Wilkin, 1695). The 1735 edition including the global section was published in Amsterdam and Paris: John Woodward, *Geographie Physique, ou Essay sur l'Histoire Naturelle de la Terre, Traduit de l'Anglois, de Monsieur Wodward, par M. Noguez, Docteur en Medecin: Avec la Réponse aux Observations de M. le Docteur Camerarius; plusieurs Lettres écrites sur la même matiere; & la Distribution méthodique des Fossiles, traduits de l'Anglois, du même M. Wodward, par le R. P. Niceron, Barnabite* (Amsterdam, 1735; Paris: Chez Briasson, 1735). For other editions see Melvin E. Jahn, "A Bibliographical History of John Woodward's {\i An Essay Toward a Natural History of the Earth}," *Journal of the Society for the Bibliography of Natural History* 6 (1972): 181–213; and Victor Ambrose Eyles, "John Woodward, F.R.S., F.R.C.P., M.D. (1665-1728): A Bio-Bibliographical Account of His Life and Work," *Journal of the Society for the Bibliography of Natural History* 5 (1971): 399–427.

nondirectionalist Earth, punctuated by major changes only because of a suspension of gravitational attraction understood as an interruption of an otherwise perpetual divine action.[30]

The nondirectionalist character of Woodward's Theory conceals an irony, however, in that Woodward defended it with a consideration that later proved a most effective evidential resource in favor of directionalist sensibilities. One of Woodward's early continental critics, Elias Camerarius, wondered whether many fossils were emplaced within the rocks on the third day of the creation week instead of as a result of the deluge.[31] Although sometimes overlooked, hexameral idiom, especially in conjunction with associated concepts of seminal reasons and the superfecundity of primordial seeds, was often part of the fabric of thought of those who denied the organic origin of fossils. Woodwardian diluvialism as an explanation for

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[28] John Arbuthnot, *An Examination of Dr. Woodward's Account of the Deluge, &c. With a Comparison between Steno's Philosophy and the Doctor's, in the Case of Marine Bodies dug out of the Earth. With a Letter to the Author concerning An Abstract of Agostino Scilla's Book on the same Subject, Printed in the Philosophical Transactions, By W[illiam] W[otton], F.R.S.* (London: Printed for C. Bateman in Paternoster Row, 1697). This work includes a global section. Arbuthnot objected to Woodward's suspension of the dissolved Earth over a cavity (17): "But the strangest thing, and, if I may so speak, the Miracle of all Miracles is, that the Water and Solid Matter now mixt together, should either float upon a Vacuum, or the Subtil Matter that came in place of the Water of the Abyss; for in the internal Sphere whose Diameter is CA, there is neither Water nor Solid Matter, but it must be left as it is for the Solid Matter to form the *Arched Expansum* upon. This is turning Nature outside inward; the Bottom of the Ocean is now supported by Water, and the Water by the Air. Well, if the Dr. gives a Reason for this too, adieu Hydrostaticks." In a dense medium, Arbuthnot objected, the rate of descent varies according to the quantity of matter relative to the surface area rather than specific gravity (22): "The Consequence of this will be, that the Parts of Animals, which were the greater Solids, could never be buried in Matter of the same Specifick Gravity with themselves." Arbuthnot cited the *Geography* of Varenius to show empirically that strata in fact are not ordered according to specific gravity. Varenius reported a pit at Amsterdam, 132 feet deep, from which one could observe that heavier strata may lie above lighter strata, and the same kind of strata are sometimes repeated. On these grounds Arbuthnot argued for gradual, successive accumulation of strata (24): "I think it is very probable they are the Sediment of a Fluid, but not precipitated at the same time, and determin'd to Subsidence in this Order, merely by their different Specifick Gravities; on the contrary their Diversity and Order seems rather to persuade that they were compiled by little and little, and at different times; which, considering the Scituation of the Country, is no hard matter to conceive." Citing another anomaly, the wells of Modena, reported by Ramazzini, Arbuthnot suggested that particular exceptions to Woodwards rule are endless. There are shells and flints in the Chalk, and many occasions where (25): "Bodies of different Specifick Gravities are found buried in the same stratum." Arbuthnot summarized his critique with customary sarcasm (26): "It is strange that the Laws of Gravity, which have been violated in so many particulars, in raising the Water of the Abyss, and making a lighter Body, descend in its room; in sustaining Minerals in Water, and stopping them in their Descent before they reach'd the Centre; in placeing the heaviest Solids in the upper Strata, &c. I say, it is strange the same Laws of Gravity should place a few Shells with as much Nicety, as the Doctor does in his Collection, not transgressing so far as a fifteenth part."

[29] The non-causal epistemic aim of phenomenalism is described on page 34ff.

[30] Woodward's Theory is nondirectionalist according to the usage of terms explained in "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22 (see especially Simpson's distinction between directionalist and nondirectionalist views quoted on page 26). The best study of the development and reception of Woodward's Theory explores the relations between antiquarianism and thinking about the Earth in the seventeenth century; Joseph M. Levine, *Dr. Woodward's Shield: History, Science, and Satire in Augustan England* (Berkeley: University of California Press, 1977).

the emplacement of fossils had far less appeal to those like Camerarius who suspected that some of the fossils originated inorganically prior to the gathering of the waters, a position which would allow a tranquil deluge.[32] Woodward responded to Camerarius with the argument that the accidental forms of marine fossils betrays their successive, historical, organic origin. For example, "There are also found in the Earth the Teeth of Fishes ground down, and worn away, in the very same Manner as the Teeth of those Kinds of Fishes, taken at Sea, usualy are, by chewing their Food."[33] Additional artifacts evidencing the contingencies of organic life include bore-holes by which the shellfish were eaten, and the burial of body fragments instead of whole organisms: one isolated leg bone, a single tooth, or just the upper or lower shell of a bivalve.[34] Woodward described the disposition of fossils

> of the very same Kind, some small, others large: some young, others old: some immature, others full grown: and, in a Word, small Ones affixed to the larger, or those which are young to the Old Ones, just in the same Manner as they commonly are found at Sea, for their better Security against the Shocks and Injuries of the Tides and Storms. These certainly give plain Proof that they were not all created together; but *generated successively, and at different Times*.[35]

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31 Elias Camerarius, *Dissertationes Taurinenses epistolicæ, physico-medicæ. Ad Illustr. Ital. ac German. quosdam medicos scriptæ, continentes Annotationes in varia modernorum, Dn. de Noües cumprimis, ac Dn. Woodwardi Scripta atque Experimenta* (Tübingæ: Joh. Georgii Cottæ, 1712), 346-347. Although not providing the "greater Work" he continued to promise, Woodward answered Camerarius in John Woodward, *The Natural History of the Earth, Illustrated, Inlarged, and Defended. To which are added, Physical Proofs of the Existence of God, his actual incessant Concurrence to the Support of the Universe, and of all Organical Bodyes, Vegetables, and Animals, particularly Man; with Several Other Papers, On Different Subjects, never before printed*, trans. Benjamin Holloway (London: Printed and sold by Tho. Edlin, 1726).

32 In his fifth conjecture, Camerarius asserted that it is "no absurdity to suppose God to have made some Analogy and Resemblance betwixt Marine and terrestrial Bodyes, by creating various Kinds of Stones representing the Forms of Sea-Shells." Camerarius, 348. Woodward (1726), 149. "Regero, nec perpetuum id esse, nec eandem probare originem; Nec repugnare arbitror, Deum quandam inter Marina terrestriaque concreta ratione figuræ similitudinem atque analogiam effecisse, creatis lapidum speciebus, quæ conchas referrent marinas externa sua specie; quæ proin suas quoque servent species, habeantque in generibus suis perpetuam figuræ ejusdem constantiam, & quædam per gradus magnitudinis incrementa ac varietates." Camerarius, 348-349.

33 Woodward (1726), 151

34 Woodward (1726), 151-153.

35 Woodward (1726), 135-136; italics added.

For Woodward the fossils lived successively at different times but, in his ahistorical temporal sensibility, their emplacement occurred once for all in a single catastrophic event, the preternatural dissolution of the world at the deluge.

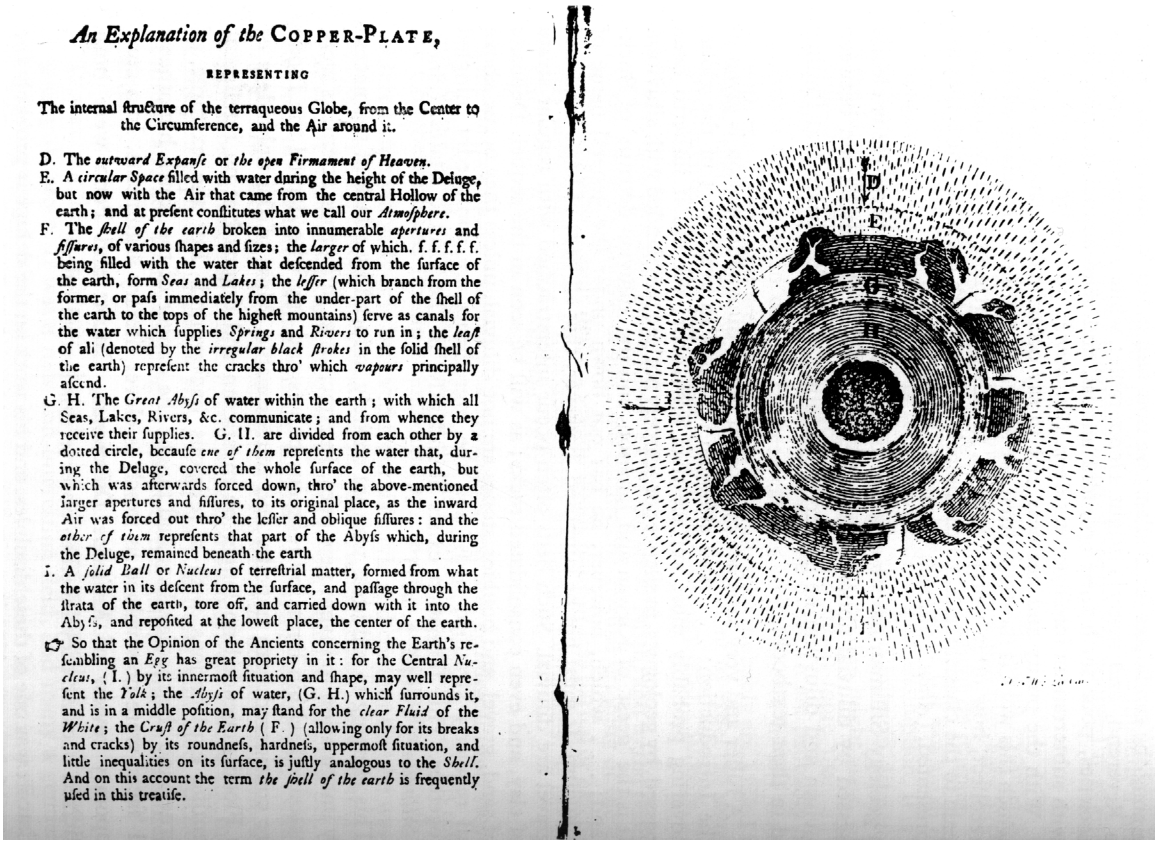
FIGURE 195. Scheuchzer, *Herbarium diluvianum* title page detail. Note fossil shells in the foreground, unmistakably explained by the deluge.

Other writers who similarly privileged fossil evidence, accepted their organic origin, and attributed their emplacement in the rocks to the deluge included the encylopedist John Harris[36]; Johann Jakob Scheuchzer, whose *Herbarium diluvianum* (1723) described the fossils he observed in the Swiss Alps (Figure 195)[37]; and Alexander Catcott (1725–1779), whose *Treatise on the Deluge* (1761; Figure 196)[38] followed John Hutchinson's (1674–1737) synthesis of aspects of Woodward's Theory with Anglican theology and English mining experience.[39] By no means were these diluvialists in complete agreement with Woodward, but they did share a common emphasis on the geological importance of the deluge.

[36] John Harris, *Remarks on some Late Papers, Relating to the Universal Deluge: And to the Natural History of the Earth* (London: Printed for R. Wilkin, 1697); and John Harris, *Lexicon Technicum: or, An universal English dictionary of arts and sciences: Explaining not only the Terms of Art, but the Arts Themselves*, 2 vols. (London: Printed for Dan. Brown, 1704–1710), s.v. "deluge," "strata," "earthquakes," and "springs."

[37] Johann Jakob Scheuchzer, *Herbarium diluvianum, collectum à Johanne Jacobo Scheuchzero, Editio novissima, duplo auctior*, Editio Novissima (Lugduni Batavorum, P. Vander Aa, 1723). On Scheuchzer see Gavin R. DeBeer, "Johann Gaspar Scheuchzer, F.R.S., 1720-1729," *Notes and Records of the Royal Society of London* 6 (1948): 56–66; and Hans Fischer, *Johann Jakob Scheuchzer: Naturforscher und Arzt*, vol. 175 of Naturforschende Gesellschaft, Zürich, Neujahrsblatt (Zurich: Leeman, 1973). Scheuchzer's portraits of the creation week are included in the Appendix.

[38] Alexander Catcott, *Treatise on the Deluge* (London: Sold by M. Withers and D. Price in Oxford, 1761). On Catcott see Michael Neve and Roy Porter, "Alexander Catcott: Glory and Geology," *British Journal for the History of Science* 10 (1977): 37–60. This insightful study exemplifies conventional views of Theories of the Earth critiqued in Part I. For example, Neve and Porter write (p. 39): "To call their work part of an independent science of 'geology' would be anachronistic. For these theories issued out of comprehensive religious and natural philosophical problems of Creation, the cosmos, and matter. They treated the earth as a planetary body within a cosmic system. They discussed the formation of matter, the creation of the universe, and of the earth within it, and the origins of life. They were more concerned with the earth's elementary physical properties (its figure, dimension, mass, internal composition, and declination) than with those features that were later to become the central domain of 'geology'—its strata, fossils, landforms. Their chronological trajectory swept from Creation to Parousia.... they conceived the problems, methods, and solutions of a proper understanding of the earth on a scale foreign to what became characteristic of later geology. They saw the planet earth within a cosmic physical theology. This view generally did not spring from any deep personal research by their authors into the local significance of rocks and landmasses. They depended much more upon deductions from astronomical, physical, and chemical evidence, as well as upon humanistic, historical testimony, and subtle traditions of scriptural exegesis." Chapter 1 agrees that Theories of the Earth dealt with comprehensive problems in natural philosophy, unlike nineteenth-century fields of science including geology. Chapter 2 discusses some of the problems of characterizing Theories of the Earth as essentially cosmological exercises. Chapter 3 explores some of the problems raised by trying to interpret Theories of the Earth with reference to "those features that were later to become the central domain of 'geology'." Nineteenth-century fields such as geophysics and planetary physics, as well as many geologists (such as James Dwight Dana and Arnold Guyot, considered in the Epilogue) continued to articulate a broad chronological vision from creation to the end of the Earth. As a textual tradition Theories of the Earth engaged a wide variety of arguments based on both empirical evidence and textual knowledge; Chapter 1 suggests that such interdisciplinarity is both productive and constraining, analogous to interdisciplinary research today on problems such as mass extinctions or life on other worlds. Neve and Porter continue (p. 40): "We are not arguing that these theories were 'unempirical', but that observations of the earth's crust were rarely of overriding importance and that the empirical evidence actually used was not chiefly observations about rock masses, strata, and fossils derived from fieldwork. Above all, it was exceptional for a theorist to derive his theory from fieldwork conducted by himself. Thus Hooke's lectures on earth history incorporated much empirical evidence, but almost none of it was his own. This was also the case with Ray, who did no fieldwork in the last thirty productive years of his life." Without imputing a technical tradition of "fieldwork" in a geological sense to early Theories of the Earth, one may note that first-hand observations of volcanos, strata, fossils, landforms, mines or mineralogical formations were made by Steno, Kircher, Woodward, Hooke (on the Isle of Wight), Robinson, Strachey, Bourguet, Whitehurst, Werner, Pallas, Saussure, Deluc, Hutton, Cuvier, and many others in search of "the theory of the Earth." Sweeping generalizations about Theories of the Earth fail to recognize their character as a contested textual tradition.



An Explanation of the COPPER-PLATE,

REPRESENTING

The internal ſtructure of the terraqueous Globe, from the Center to the Circumference, and the Air around it.

D. The *outward Expanſe* or *the open Firmament of Heaven*.

E. A *circular Space* filled with water during the height of the Deluge, but now with the Air that came from the central Hollow of the earth; and at preſent conſtitutes what we call our *Atmoſphere*.

F. The *ſhell of the earth* broken into innumerable *apertures* and *fiſſures*, of various ſhapes and ſizes; the *larger* of which. f. f. f. f. f. being filled with the water that deſcended from the ſurface of the earth, form *Seas* and *Lakes*; the *leſſer* (which branch from the former, or paſs immediately from the under-part of the ſhell of the earth to the tops of the higheſt mountains) ſerve as canals for the water which ſupplies *Springs* and *Rivers* to run in; the *leaſt* of all (denoted by the *irregular black ſtrokes* in the ſolid ſhell of the earth) repreſent the cracks thro' which *vapours* principally aſcend.

G. H. The *Great Abyſs* of water within the earth; with which all Seas, Lakes, Rivers, &c. communicate; and from whence they receive their ſupplies. G. H. are divided from each other by a dotted circle, becauſe *one of them* repreſents the water that, during the Deluge, covered the whole ſurface of the earth, but which was afterwards forced down, thro' the above-mentioned larger apertures and fiſſures, to its original place, as the inward Air was forced out thro' the leſſer and oblique fiſſures: and the *other of them* repreſents that part of the Abyſs which, during the Deluge, remained beneath the earth

I. A *ſolid Ball* or *Nucleus* of terreſtrial matter, formed from what the water in its deſcent from the ſurface, and paſſage through the ſtrata of the earth, tore off, and carried down with it into the Abyſs, and repoſited at the loweſt place, the center of the earth.

☞ So that the Opinion of the Ancients concerning the Earth's reſembling an *Egg* has great propriety in it: for the Central *Nucleus*, (I.) by its innermoſt ſituation and ſhape, may well repreſent the *Yolk*; the *Abyſs* of water, (G. H.) which ſurrounds it, and is in a middle poſition, may ſtand for the *clear Fluid* of the *White*; the *Cruſt of the Earth* (F.) (allowing only for its breaks and cracks) by its roundneſs, hardneſs, uppermoſt ſituation, and little inequalities on its ſurface, is juſtly analogous to the *Shell*. And on this account the term *the ſhell of the earth* is frequently uſed in this treatiſe.

FIGURE 196. Catcott, *Treatise on the Deluge* (1768). Global section.

Description. Note the cavernous crust (F) now filled with seas (f) and communicating passages; the watery abyss (G, H); and a central earthy core (I). At the end of the deluge air that is now part of the Earth's atmosphere was expelled from region G, as the receding flood waters took its place. This explanation is not far different from that of Woodward, Leibniz, or Silberschlag [below], among others. In the last paragraph of the explanation of the plate, Catcott asserted that the ancients believed the Earth's structure is like an egg. This Burnetian claim is discussed above, page 465ff.

[39] Hutchinson's theories were published in twelve volumes (none of which have global sections or views), beginning with *An Essay Toward a Natural History of the Bible, Especially Of some Parts which relate to the Occasion of revealing Moses's Principia*, 3d ed., vol. 1 of *Hutchinson's Works*, 12 vols. (London: Printed for J. Hodges, at the Looking-Glass, over-against St. Magnus's Church, London-Bridge, 1748). Cf. David S. Katz, "The Hutchinsonians and Hebraic Fundamentalism in Eighteenth-Century England," in *Sceptics, Millenarians and Jews*, ed. David S. Katz and Jonathan I. Israel (Leiden: E. J. Brill, 1990); C. B. Wilde, "Hutchinsonianism, Natural Philosophy and Religious Controversy in Eighteenth Century Britain," *History of Science* 18 (1980): 1–24; Geoffrey N. Cantor, "Revelation and the Cyclical Cosmos of John Hutchinson," in *Images of the Earth: Essays in the History of the Environmental Sciences*, ed. Lisa J. Jordanova and Roy S. Porter, BSHS Monographs, no. 1 (n.p.: The British Society for the History of Science, 1978), 3–22; and Albert J. Kuhn, "Glory or Gravity: Hutchinson vs. Newton," *Journal of the History of Ideas* 22 (1961): 303–322.

§ 4. Mines, Mountains and Strata: Two Early English Theories

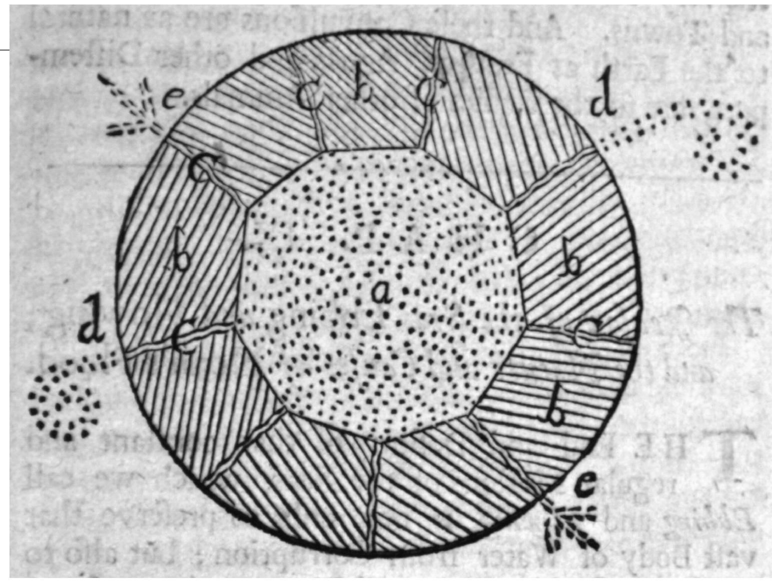


FIGURE 197. Thomas Robinson, *Anatomy of the Earth* (1694), p. 19. HSCI.

Explanation. Central chaos of agitated air (a) within the crust (c). Airy exhalations (d) through "Joynts of the Earth" produce hurricanes. Fiery exhalations (e) produce volcanos and earthquakes.

The Reverend Thomas Robinson's Theories of the Earth were dedicated "to the gentlemen miners" who afforded him "opportunities... of being sometimes Underground." Written almost entirely against Burnet and Woodward's Theories of the Earth, Robinson appealed to contemporary mining experience bolstered by a Mosaic mineralogical system of the Earth based on hexameral exegesis. Robinson presented his Theory as the "product of 20 Years Experience and Observation; for so long have I been concerned in the Inspection of under-ground Works of several kinds."[40] He expressed approval of the general outline of the "Stenonian Hypothesis" of "the Origine of Mountains from the Disruptions and Changes of the Strata of the Earth" in a two-part cycle.[41] Against both Steno and Woodward, Robinson argued that fossils are formed in the bowels of the Earth by natural means[42]; because they are not of organic origin there is no need supernaturally to place them there by the finger of Woodward's God.[43]

[40] *New Observations*, Preface.

Contrary to Woodward, Robinson reported evidence from the strata that his "darling Notion" regarding specific gravity is "notoriously false in Fact and Nature."[44]

The brief *Anatomy of the Earth* (1694) includes his first global section (Figure 197); the second one reprinted here (Figure 198) is from *New Observations* (1696), which also includes a treatise on meteorology. The third volume, *An Essay Towards a Natural History of Westmorland and Cumberland* (1709) contains a treatise on hexameral commentary, although all three volumes are organized around hexameral exposition (even *New Observations* begins with an extended interpretation of Genesis 1). The full titles of Robinson's three volumes rehearse a

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41 Robinson described what he believed were Steno's views of the globe as a whole: "The same Steno, in his *Prod*. places about the central Fire of the Earth, a huge Sphere or Abyss of Waters; which, according to him, supplies the Earth with Springs, the Air with Vapours, and was sufficient for the general Deluge, when by the Force of the subterraneous Fires, it was thrust and forced up, whereby the Globe was broken to pieces, and dissolv'd in the vast Fluid." Etc. based on descriptions in the *Monthly Miscellaneous Letters*, vol. 1, no. 22, pp. 561, 566, vol. 2, No. 2, pp. 49-57; *Phil Trans*, no. 219, pp. 181-201." While this reading of a central fire and surrounding abyss is consistent with the *Prodromus*, it goes beyond what Steno explicitly asserted. However, Robinson acknowledged that his views were not thoroughly Stenonian, asserting that "The Devil's Causeway in Ireland [*sic*; usually called the Giant's Causeway] should persuade any observer of the error not only of Woodward's specific gravity theory, but also of the theories of Columna, Steno, Scilla, Boccone, Grandius, et al." Robinson's general outline of Steno's Theory emphasized the two cycles: "Note, that Steno proves the Earth to have been twice fluid, twice plain and dry, twice scabrous and craggy; the first was at the original Chaos, the second at the Flood; . . . . This agrees with what Mr. Whiston delivers in many places of his New Theory. To which we may add that the simple antediluvian Beds on the high Mountains, destitute of Heterogenous Solids, may be laid open by the washings away of the incumbent Diluvian Sediments or compound Beds, by the Torrents of Rains, which carry down those Crusts and Bodies along with them." Robinson was more favorable to Whiston than to either Burnet or Woodward, perhaps because Whiston (like Steno) upheld interpretations of the third day and opposed Burnet's conception of the smooth Paradisiacal globe, but he regarded Whiston's Theory as too mechanical, "depending too much upon mechanical & necessary Laws" such that "Grand Revolutions" of creation and cataclysm "may befall the Moon and all the Planets, without any respect to Inhabitants," i.e., disjunctive of their moral history. Yet in Whiston's theory, Robinson averred, there is evidence of a "noble Genius" deserving of some charity.

42 *New Observations*, 17: "this establish'd Course of Nature, or these Laws and Rules which the Divine Wisdom gave to the Second Causes to work by, he never interrupts or varies from; but upon great and extraordinary occasions...."

43 Dr. Lister "proves beyond all contradiction, that real perfect Shells are frequently found in the Bladder, Kidneys, Imposthumes, and other Cells of Animal Bodies; and if so, why need we force them into the midst of Quarries and Rocks by dissolving the whole Frame of Nature for their Sakes?" In *Anatomy of the Earth* Robinson explained that the curse weakened the Plastick powers so that now only insects and imperfect creatures are naturally produced—or occasionally higher "voluntary Productions": "For, in sinking of a Coal-Pit, I have found a large Toad in the closure of a stone near Three fathom under ground; where it could hardly have any other Generation, than what was purely Spontaneous, being (as it should seem) produced out of a poysonous Matter enliven'd by the Subterranean-heat...." Such productions absorb harmful vapors to the benefit of life on Earth.

44 "the Strata, Layers, or Beds of Sediments... do not lie according to their different Weights, or according to the Statick Laws of descent of Solids in Fluids; for the Strata of Marble, and other Stone, of Lead, and other Metals, lye often near the top or Superficies, having many lighter Strata under them...."

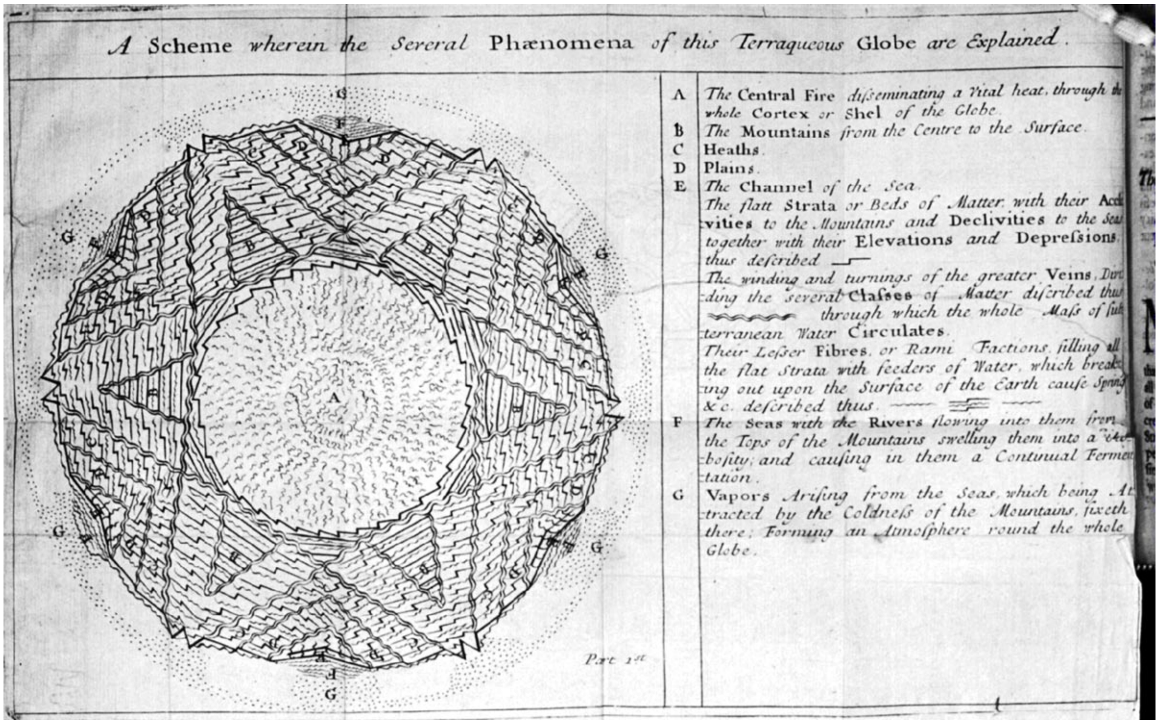

FIGURE 198. Thomas Robinson, *New Observations* (1696). Global section.

Caption. "A Scheme wherein the Several Phaenomena of this Terraqueous Globe are Explained." A. The Central Fire disseminating a Vital heat, through the whole Cortex or Shel of the Globe. B. The Mountains from the Centre to the Surface. [A star of David pattern.] C. Heaths. [superincumbent upon mountains] D. Plains. [superincumbent upon heaths] E. The Channel of the Sea....[45] F. The Seas with the Rivers flowing into them from the Tops of the Mountains swelling them into a Gibbosity; and causing in them a Continual Fermentation. G. Vapors Arising from the Seas, which being Attracted by the Coldness of the Mountains, fixeth there; Forming an Atmosphere round the whole Globe.

Description. Note the central fire and the mountainous skeleton of the globe. As an integral part of the Earth's structure, mountains must have existed before the Deluge. They are also necessary for the Earth's water cycle: Vapor rising from the seas (G) returns to the Earth at the tops of mountains, and mountains contain passages for subterranean circulation of water.

[45] The caption for "The Channel of the Sea" continues: "The flatt Strata or Beds of Matter with their Acclivities to the Mountains and Declivities to the Seas together with their Elevations and Depressions thus described [stairstep line; located within mountains, heaths, plains]. ¶ The winding and turnings of the greater Veins, Dividing the several Classes of Matter discribed thus [double squiggly lines separating mountains from heaths, heaths from plains] through which the whole Mass of subterranean Water Circulates. ¶ Their Lesser Fibres, or Rami Factions, filling all the flat Strata with feeders of Water, which breaking out upon the Surface of the Earth cause Springs & c. described thus [single squiggly lines, often between strata]."

litany of favored phrases in Theories of the Earth.[46] All three books elucidate, elaborate, and defend a similar position; here we limit our focus to the second book and its global section, and describe how hexameral idiom, mystical traditions, and the "chain of being" of neoplatonic theology shaped how Robinson developed and used his experience of mines.

On the second day, the firmament divides the waters above from the waters below. For Robinson the firmament of heaven is the space between the surface of the lower waters and the vortex of the Moon, which became filled with air as the fogs and mists condensed. As Robinson described it, the waters sank toward the center, unevenly compressing the strata and cementing them together with their minerals. As pointed out in the discussion of Camerarius, if one accepted the inorganic origin of fossils it was plausible to attribute them to the creation week as well as the deluge. Contrary to Steno (but much like Whiston), for Robinson dip and rise were characteristic of the strata from their origin, even before the third day. As the waters compacted and cemented the strata the central fire baked and consolidated stones and minerals of a fiery nature: "By these Natural Gradations the Earth became fixt upon its Center, and the Waters a fluid body moving and circulating about it; and they both made one Terraqueous Globe."[47]

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[46] Thomas Robinson, *The Anatomy of the Earth* (London: Printed for J. Newton, at the Three Pigeons in Fleet-Street, 1694), Thomas Robinson, *New Observations on the Natural History of this World of Matter, and this World of Life: In Two Parts. Being a Philosophical Discourse, grounded upon the Mosaic System of the Creation, and the Flood. To which are added Some Thoughts concerning Paradise, the Conflagration of the World, and a Treatise of Meteorology: With occasional Remarks upon some late Theories, Conferences, and Essays* (London: Printed for John Newton at the Three-Pigeons, 1696); Thomas Robinson, *An Essay Towards a Natural History of Westmorland and Cumberland, Wherein an Account is given of their several Mineral and Surface Productions, with some Directions how to discover Minerals by the External and Adjacent Strata and Upper Covers, &c. To which is Annexed, A Vindication of the Philosophical and Theological Paraphrase of the Mosaick System of the Creation, &c* (London: Printed by J. L. for W. Freeman, at the Bible against the Middle-Temple-Gate in Fleet-street, 1709). The first of these works is briefly discussed in F. J. North, "The Anatomy of the Earth: A Seventeenth-Century Cosmogony," *Geological Magazine* 71 (1934): 541–547. As Rector of Ousby in Cumberland from 1672 through 1719, Robinson appears to have combined natural history with divinity in typical English fashion: "After service on Sundays he presided at a kind of club at the village alehouse, where each member spent a sum not exceeding one penny; he was also a warm encourager of sports, especially football. His leisure he devoted to collecting facts about the mining, minerals, and natural history of the counties of Cumberland and Westmoreland, which he put before the world in a quaint 'Anatomy of the Earth,'... he was married, and had eight children." *DNB*, vol. 17, p. 46.

[47] Robinson, *New Observations*, 27.

On the third day, the waters gather together and dry land appears. Robinson described it with a macrocosm-microcosm analogy:

> Tho' this great Embrio was ready for birth and to breath in fresh Air; yet it could not be deliver'd from this great Bag of Water, wherein it was enclos'd, by any innate Power it had in it self, without a Supernatural Assistance: The Almighty was pleas'd therefore to play the Midwife, and to deliver it by breaking of this great body of Water; and by dividing of the sweet from those of a Saline and Brakish Nature.[48]

At this time (not after the deluge) the present water cycle began: salt water flowed into its channel; thinner fresh water penetrated into the strata and saturated it.[49] Against Burnet's description of the smooth antediluvian globe, Robinson argued that the initial variety of matter produced on the second day would result in inequalities: "it cann't be imagin'd that all this variety of Matter would settle in a Figure Spherically and Mathematically round."[50] As his account of the third day suggested, winds and rain depend on the constant flux and reflux of the Sea and upon the inequalities of the surface of the land; therefore Burnet's Earth would not be habitable, but would be baked to a crust by the sun. Finally, a variety of animals require a variety of climatic conditions, not an homogenous Paradisiacal globe.

In addition to hexameral idiom, a second (related) context which provided the basis for Robinson's understanding of mining experience was a variety of mystical traditions, including hermetism and the *prisca sapienta* with a strong emphasis upon microcosm-macrocosm analogies, not unlike Becher or even Fludd. Robinson argued that the Mosaic System of Creation

48 Robinson, *New Observations*, 28.

49 "And all the Veins and Pores of the Earth being now Saturated with sweet Water; the Subterranean Lymphed-ucts, or underground Water-works began first to bubble up and play from the tops of the highest Mountains; from whence the Rivers took their first rise, and began to form their courses to the Sea; and by their rapidity and weight continually pressing in upon her from all sides, swell'd her up into a Gibbosity, and forc'd her into a constant flux and reflux, which reciprocation of Motion causing in her a boyling Fermentation, the sweet Water does disentangle it self from the Salt; and being lighter, riseth up in Fumes and Vapours, which fly abroad until they be condens'd into Clouds, which falling down in showers of sweet Water upon the Earth becomes the Succus Nutritivus of the fleshy part of it; giving not only a vital nourishment to the several Kinds of Animals living on the outer Coat or Skin of it; but repairing the Subterranean Waters by preserving them from wasting." Robinson, *New Observations*, 29–30.

50 Robinson, *New Observations*, 33.

is more reliable than recent theories because it was based on the knowledge of the Egyptians and the patriarchal tradition handed down from Adam. Robinson's essays in natural history attempted to recover a Mosaic understanding which blended natural history with natural philosophy, the writings of the ancients, biblical exegesis, and theology:

> In this most excellent System, Philosophy, Divinity and Mystery seem to be so closely interwoven that it wou'd be a Matter of great Difficulty (if not Impossibility) for any, unless such as are well skill'd in the Cabalistical Traditions and Mythology, to unravel the Contexture and distinguish its parts.[51]

Robinson developed in intricate detail analogies between parts of the Earth and the human body. To take but one example, the sulfureous central fire is the heart of the Earth. Both produce heat to enliven the body or the Earth. As the heart causes the pulse, "so the Central Fire is as well the cause of the Ebullition of Springs..." As the heart causes the blood to circulate, so the central fire causes the circulation of subterranean water through the Dykes, Rakes, and Fissures which are the veins of the Earth. As the heart imparts color to the blood, so the central fire colors the variety of earths and minerals as they ferment.[52] In addition, as the heart makes the body move, so the central fire causes diurnal motion: "The Central Fire, by running a perpetual Round within the Boundaries of its own Infernal Vault, carries the Shell of the Earth about with it, and is the cause of its Diurnal Motion."[53]

[51] "Rabbies are of opinion that God directed Moses, and the rest of the holy Pen-Men, frequently to make use of Metaphors, Allegories, and other Schematical Forms..."

[52] Robinson, *New Observations*, 35: "Analogous to that vital Flame which is seated in the Heart or Center of all Animals; for as that by its Vital heat enlivens the whole Body; so this Central Fire by that Vital warmth it disseminates through the whole mass of Matter, enlivens it; and gives as well to the several Strata of Stones, Metals, Minerals and other subterranean Earths, their degrees of Consolidation; as to the several kinds of Ores, their different degrees of Purity and Perfection." Like Kircher and Becher, for Robinson the central fire was a volatile, sulfureous chaos, identified with hell in an attached discourse: A Discourse concerning the Conflagration of this material World; the Local Hell; its outmost Boundaries, or Abraham's Gulph. ". . . it is apparent, that one Third part of this Globe is Volatile, another Third part Combustible and Inflammable, and only a Third part Fluid. Which Third part preserves the Harmony and Conspiracy of its Parts, which makes the Cement and Temperament of the whole Body, and if this should once be broken, and the Volatile and Fluid suffered to act their Antipathies upon each other, the whole Frame and Structure would presently be dissolved, and all things shufled into their Original Chaos and Confusion." Robinson, *New Observations*, 173.

[53] Robinson, *New Observations*, 36–37. In *Anatomy of the Earth* Robinson similarly commended the diurnal motion of the Earth as the consequence of central fermentation; as the motion of the "confus'd and undigested Matter" within the central cavity carries the Shell of the Earth along with it in regular daily motion, which also influences the growth of metals (pp. 21–24).

Robinson rejected Copernicanism in favor of a geocentrism that was inextricably related to his hierarchical neoplatonic theology which envisioned orders upon orders of beings of different degrees of perfection.[54] In a second illustration Robinson illustrated the gradations of life as a chain of being embodied within a cosmic section (Figure 199), a fold-out plate of the "concatenations of life" extending from the center of the world out to a "near Approach to the Divine Essence." At one end of the chain, and at the circumference of the world, is God "who, as an Universal Soul, actuates the whole World, by giving of the several degrees of Life and Perfection to all the Creatures in the Animal World, as they are plac'd in Orbs or Spheres nearer or at a greater distance from his Divine Essence."[55] Robinson justified the study of the Earth within a unity of knowledge, for "by these gradations we may either ascend up to Heaven, where God Almighty resides in Infinite Glory and Perfection, or from thence descend to the hidden and dark Regions of Matter."[56]

[54] *New Observations*, 5-9. "... the Great and Almighty Monarch of the Universe may be supposed, first to have laid the Foundations of those SuperCoelestial Regions of unaccessable Light, the Royal Chambers of his own most Glorious Presence; where he sits in great Majesty attended with an innumberable retinue of the most Noble Angels his Courtiers: After these he creates the highest of the Coelestial Spheres, in which he placed Thousands of Royal Mansions, where the Arch-Angels and Brighter Cherubins, the chief Ministers of State in that Coelestial Kingdom keep their residence: And these are the Morning Stars . . . . After these God created the inner or lower Spheres, in which he placed innumberable numbers of bright, lucid and Aetherial Globes; wherein the inferior Angels and Domestick Officers do inhabit, and these the Scripture stiles Ministering Spirits. And these differ in Office, Power and Light, as they are placed in Spheres nearer, or at a distance from the Regions of Light . . . . After the finishing of these Inner Courts of this Royal Palace, last of all God created this Material Globe or Outer Court; and made it the Center of the Universe: And it's built of the Rubbidge, Dross and Sediment of the whole Creation, and inhabited with the meanest of Creatures, and lowest degree of Life and Perfection, which may most properly be called God's out servants; over which he has placed Man Deputy Lord Governour." Robinson, *New Observations*, 6-7.

[55] Robinson, *New Observations*, 13.

[56] Robinson, *New Observations*, 13.

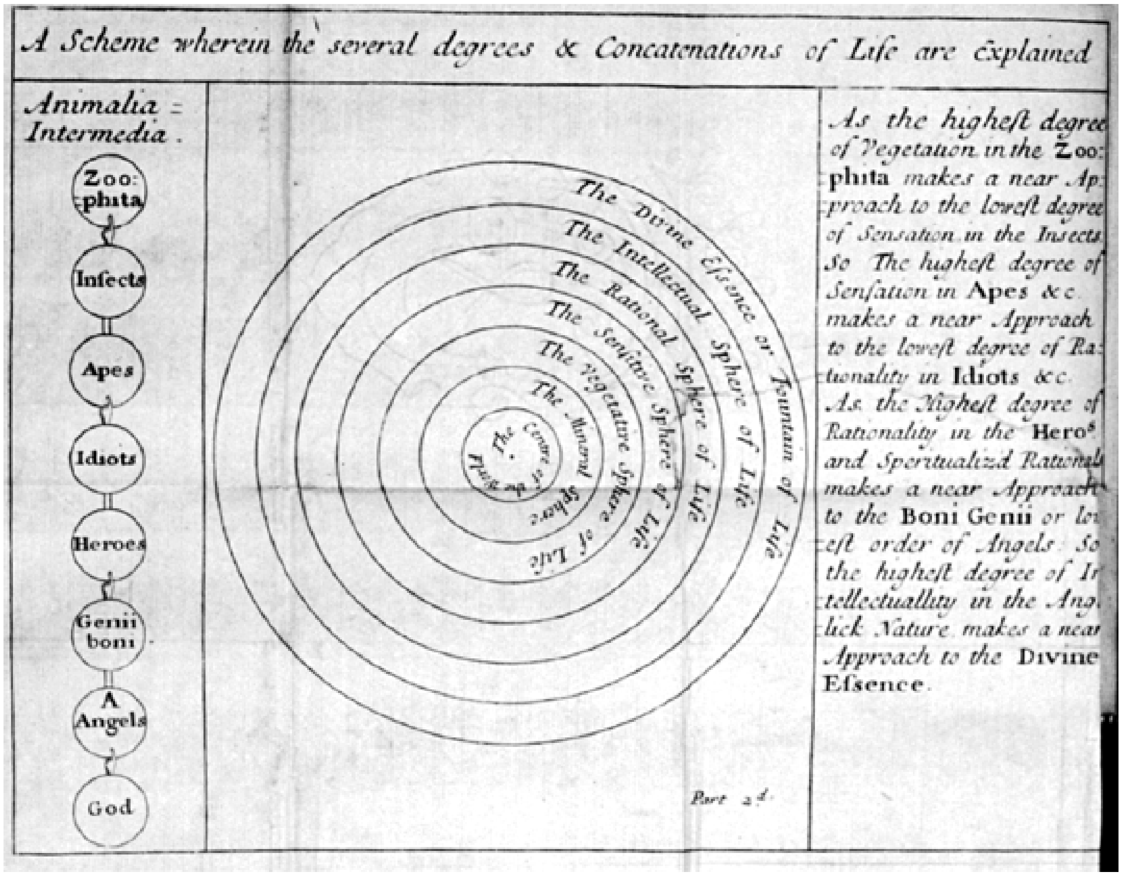

FIGURE 199. Robinson, *New Observations*. The Chain of Being superimposed upon a cosmic section.

With this mix of hexameral idiom, mystical traditions, and neoplatonic theology Robinson forged a thoroughly temporal interpretation of the structure of the Earth known through mining experience. As he laid out his first two preliminary postulates, Robinson emphasized temporal aspects of the hexameral succession, and asserted that the creation week took longer than six twenty-four hour days:

> 1. That this Natural World was created in a Natural Way, by the Agency of second Causes; God Almighty concurring with them by his Direction and Approbation in these Words (He saw that it was good.)
>
> 2. That the work of the Creation cou'd not, in a natural way, be compleated in so short a time as six days; for as it cannot be easily imagined that all the Solid Strata and Beds of Iron cou'd be digested into such good order, as we find them in; and receive their several Degrees of Consolidation in that time: Neither can it be Sup-

> pos'd that all these different natures in the Vegetative and Animal Sphere of life shou'd grow up to such a degree of Perfection, that Adam cou'd eat Ripe fruit in Paradise of six days Production: And that all the Beasts of later birth cou'd in that time get Strength to appear before him.

Robinson argued that the Divine Essence could not "wrap up it's self in sloth and idleness," but would always express itself in vigorous activity. Therefore the creation was temporal:

> this Universal Fabrick of the World was not created at one stroke, by an imperious Fiat; for tho this might have been consistent with Infinite Power; yet it would not have been agreeable with Infinite Wisdom, which consists in Deliberation, Counsel and Contrivance.[57]

The third day involved not a single event, but a series of productions over a longer time (Table 64). The mountain peaks were the first dry land to appear (the tips of a star-like pattern in Figure 198), comprised of rocks of a hot quality formed by the "Ebullition of Matter, occasion'd by the Central Fire when it was in its full Strength and Vigour."[58] Mountain heaths, whose strata are tilted because they were laid down by moving water, were the second kind of dry land to appear.[59] These strata, superincumbent upon mountains in Figure 198 and separated from mountains by double squiggly lines, include coal-bearing strata. Afterward the plains and valleys appeared, deposited by more tranquil water, often displaying only

[57] Robinson, *New Observations*, 5. Similarly, Robinson later explained: "The confus'd Mass of mixt Matter being thus reduc'd to several Classes and a regular Form; every Class leading to some proper Mine or Mineral, which is the finer and better digested part of that Class; as Coal, Rudle, Iron and the several Kinds of Ore; and these all lay in lax and fluid Strata or Beds, like the loose Leaves in an unpress'd Volume or Book, or like the weak joynts in a newly conceiv'd Embrio, enclos'd in a Bag of Water in the Womb of its pregnant Mother."«24.»

[58] Robinson, *New Observations*, 41. Summits associated with a cold and condensing air. Summits of the same altitude as the gibbosity of the sea.«Robinson, New Observations, 42.» Mountains are the necks of the body of the Earth, where veins concentrate and meet. "And this is the only Reason why the Heads of all the greatest Rivers in the World have their Rise from the Tops or Sides of the highest Mountains; ...."«Robinson, New Observations, 43.» The greater declivity of mountains causes rivers to flow rapidly, which press upon the sea from all sides, creating an oceanic gibbosity, which causes the flux and reflux of the tides. The same rapidity given to rivers is also imparted to mountain winds. The foundations of mountains meet in the center, forming the subterranean vault, which provides foundational support for the crust and prevents the central fire from engulfing the surface. Thus mountains are "the greatest Ornament of [the Earth's] Superficies."«45.»

[59] Robinson, *New Observations*, 46-47: "for as the Sea did gradually draw down into its Channel; its unruly Waves drove up these lesser Hills… and forc'd their Strata… to have a Rise towards them…."

a slight dip toward the sea.[60] Once the habitable land was prepared, the productions of the third day concluded with a gradual generation of plant life.[61]

TABLE 64. Robinson, Productions of the Third Day

Order of Appearance	Kind of Land	Mode of Formation	Appearance
First	Mountains	Central fire, ebullience	Most tilted
Second	Mountain heaths	Aqueous deposition	Moderately tilted, may contain coal, fossils
Third	Plains	Aqueous deposition	Least tilted
Fourth	Plant Life	Generation	

To explain the hexameral account of the Sun, Moon and stars on the fourth day, after the formation of the Earth on the third day, Robinson relied upon a phenomenalist perspective of the appearance of stars (as had Whiston):

> Thus by reducing of those waterish Fogs into the Body of the Moon, the upper Firmament or Planetary Spheres were clear'd, and the Planets, with the rest of the Stars Created in the Morning of the World, began to appear; and to send down their Aetherial and Invisible Influences upon this Globe, which were obstructed and interrupted by the Interposition of these waterish Mists.[62]

The heavenly bodies were described at this time because the passing of their influences through the atmosphere was required for the production of organic life on the remaining days.[63] From the account of the sixth day wherein Adam, ensconced in a mountainous paradise, named the animals, Robinson inferred "I presume that it can hardly be imagin'd that one Day could be sufficient for so great a Task."[64]

60 Robinson, *New Observations*, 48: "for as the Waters divided, their Strength abated, and the Flat Strata laid more level."

61 "That these Productions [plant life] were not brought forth all at once; but gradually as the Passive Matter receiv'd higher Degrees of Heat and Modification, is apparent from our observing of those Annual Productions which every Season bringeth forth." Robinson, *New Observations*, 110. Plant life originated during the first spring and summer. Robinson, *New Observations*, 125.

62 Robinson, *New Observations*, 117.

After the creation week, changes in the Earth result only from the accidental effects of earthquakes, volcanos, hurricanes, eruptions of subterranean waters (as at the Deluge), interruptions of the circulation of vapors and rain (as in the time of Elisha), violent thunders (as destroyed Sodom), etc. Such disorders arise from three kinds of "damps": central, subterrene, or aerial, depending on their source and severity. For example, central damps occur as the result of the central fire expelling water upward through the crust, which may cause an earthquake, the elevation of a mountain, hurricane winds, etc. Volcanos are the spiracles which release the central damps, and the horizontal passages in the global section (contrary to Woodward's vertical fissures) prevent most central damps from escaping onto the surface of the Earth. Were the fissures vertical as in Woodward's Theory, instead of in "crooked lines with various windings and turnings, openings and closings" (as shown in Figure 198), then the venting of these discharges would destroy the Earth's surface.[65] Noah's flood was caused by a combination of all three kinds of damps, a reuniting of the subterranean, superterranean and nubiferous waters.[66] Contrary to Woodward's dissolution of the antediluvian Earth, the only alterations were to the exterior surface of the Earth and not its mountainous skeleton.[67]

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[63] Like many of his contemporaries, Robinson held that a "Plastick spirit" forms the shapes of insects and animals in the rocks. And he accepted the idea of spontaneous generation *in situ*. "This Hypothesis is grounded not only upon the form'd Stones we meet with lodg'd in the Interior Strata of the Earth (which having the shapes and representations of Terrene and Marine Insects) cou'd proceed from no other Original than a Plastick Spirit; but also upon those Subterranean Animals, as Toads, Frogs, Asks and Clocks, which we sometimes meet with inclos'd in the Cavities and Hollows of Stone, as well as in their dry Joints. I have found a large Toad six Yards under Ground, inclos'd in the very middle of a hard Stone, where the Joint that led to it was so straight, that it wou'd not receive the thinnest Knife; so likewise great numbers of Asks, Clocks and Beetles in the dry Joints of Stones, which cou'd have no other generation, but what was from a Plastick Spirit modifying a Subterranean Vapour collected into that Cavity or dry Joint, the Vivifick Flame kindl'd a Spark of Life in them, which (by sucking in such Subterranean Vapours, as abounded in the Joints of these dry Stones, <p. 120> which had lost their Natural Feeders) were increas'd to that bulk we found them in; no doubt but the Stamina Vitæ of these Subterrene Animals are preserv'd by continual Sleeping, and the Air they breath is purely Subterranean, like Embrios in the Womb, which live by the Respiration of their Mothers...." Robinson, *New Observations*, 119-120. For Robinson, spontaneous generation of insects and fish was authorized by scripture: "Let the waters bring forth..." (p. 121). Concurring secondary causes included celestial influences, the watery matrix for the action of the Plastick Spirit and Specifick Forms, and subterranean heat acting to generate eggs in the sea-bed (p. 122). Eggs were originally generated in the first fall, and hatched the following (second) spring (pp. 122-123).

[64] Robinson, *New Observations*, 162.

[65] Robinson, *New Observations*, 62.

An interesting contrast to Robinson is John Strachey (1671–1743), who shared Robinson's interest in mining experience and illustrated his "Account of the Strata in Coal-Mines," published in the *Philosophical Transactions* in 1725, with a combination of local and global sections. As mining experience provided a greater knowledge of regularities in the local or regional sequences of formations (Figure 200), these regularities could be systematically organized and made intelligible by postulating a Theory of the Earth as a whole.[68]

[66] Robinson, *New Observations*, 79: "the collection and reuniting of such a quantity of Water as was sufficient to Drown the World, was caus'd by an Universal Damp that happen'd at that time in the whole Course of Nature." At the flood God stirred up the fermentation of the central fire, it gained ground on its watery neighbors and caused them to be expelled through every fissure to the surface: "These violent Eruptions of the Submarine and Subterranean Waters, which Moses calls the breaking up of the Fountains of the great Deep, swell'd up the Sea into such a height of Gibbosity that it forc'd the Rivers to stand back, and rise as high as their Fountain Heads, which covering all the dry Land, excepting the Tops of the highest Mountains; the Aerial Damp caus'd by the Moon's waterish Vertex pressing down the Vortex or Atmosphere of this Terraqueous Globe, did not only interrupt the Communication of the Subterranean and Aerial Waters, by causing the raising and circulation of Vapours to cease; but also by condensing the moist Air into waterish Clouds, which falling down in continual Spouts for Forty Days and Nights together . . . the Tops of the highest Mountains were cover'd Fifteen Cubits . . . ." Robinson, *New Observations*, 80.

[67] Robinson described the effects of the deluge as including the breaking up and throwing down of the uppermost strata on the tops of mountains; breaking of joints of the mountains; enlarging of the channels of rivers; whirling water formed lesser hills of sand and broken strata; deposition of great masses of uprooted trees; and fertilization of the soil. "These Alterations were not caus'd by the rising, but by the decreasing Waters; for whilst the Waters were arising, the Aerial as well as the Subterranean Damp continu'd, and the Subluniary Course of Nature was Stagnated; but as soon as God caus'd a Wind to pass over the Earth, the Damp broke, and the Waters were put into a Most violent Perturbation and Commotion; which was the only cause of all those Alterations and Devastations." Robinson, *New Observations*, 90-91.

[68] John Strachey, "A Curious Description of the Strata observ'd in the Coal-Mines of Mendip in Somersetshire," *Philosophical Transactions of the Royal Society of London* 30 (1719): 968–973; and John Strachey, "An Account of the Strata in Coal-Mines, &c," *Philosophical Transactions of the Royal Society of London* 33 (1725): 395–398. John Fuller has made a special study of Strachey and William Smith; see John G. C. M. Fuller, "The Forty-Yard Problem: A Cross-Section by John Strachey annotated by William Smith," *Archives of Natural History* 21 (1994): 195–199; John G. C. M. Fuller, "The Invention and First Use of Stratigraphic Cross-Sections by John Strachey, F.R.S., (1671-1743)," *Archives of Natural History* 19 (1992): 69–90; John G. C. M. Fuller, "The Industrial Basis of Stratigraphy: John Strachey, 1671–1743, and William Smith, 1769–1839," *Bulletin of the American Association of Petroleum Geologists*, 53 (1969): 2256–2273.

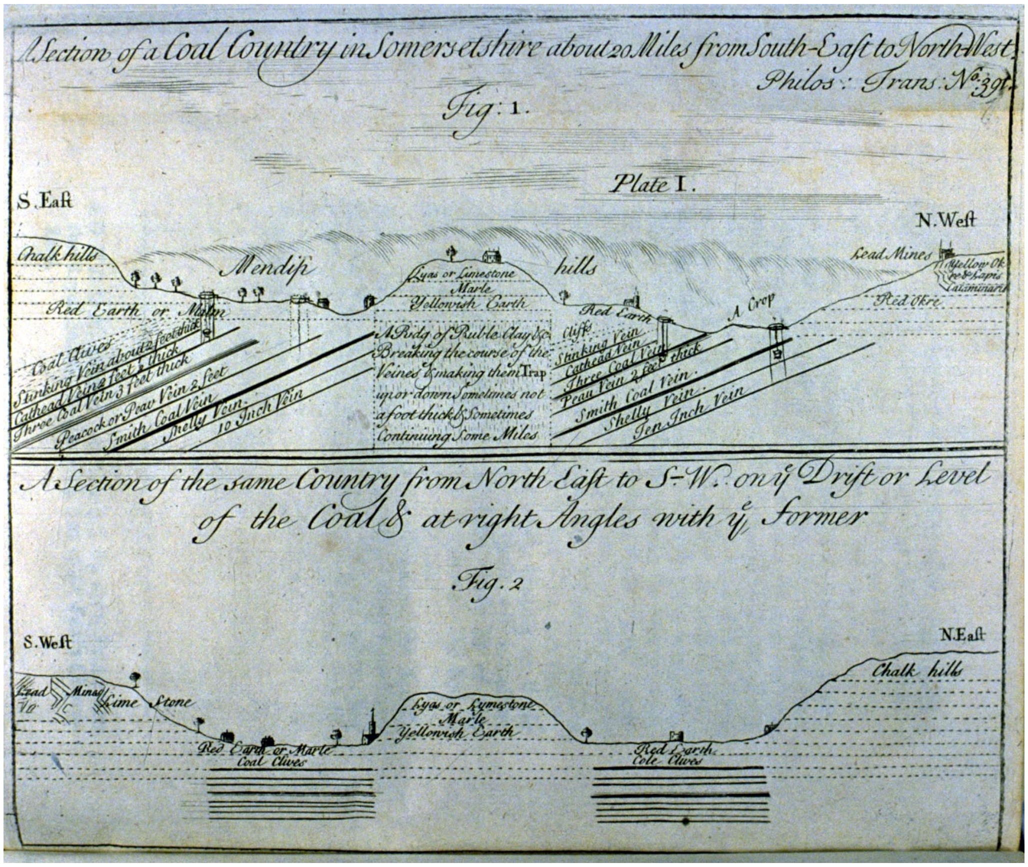

FIGURE 200. Strachey (1725), local sections.

Caption. "A Section of a coal country in Somersetshire about 20 miles from SE to NW."

In complete contrast to Steno's principle of original horizontality and the various conceptions of other Theorists of the internal structure of the Earth, for Strachey the strata spiral all the way down to the Earth's core. Their regular order of superposition at the surface results from the initial impulse given during the creation week, which caused the yet-unhardened Earth to begin its diurnal rotation (Figure 201). This sudden initiation of diurnal rotation explains the eastward dip of English strata, as minerals spiral westward like leaves of a rolled up paper book. A corollary of the theory is that each stratum detected in underground mines is exposed somewhere on the surface of the Earth.

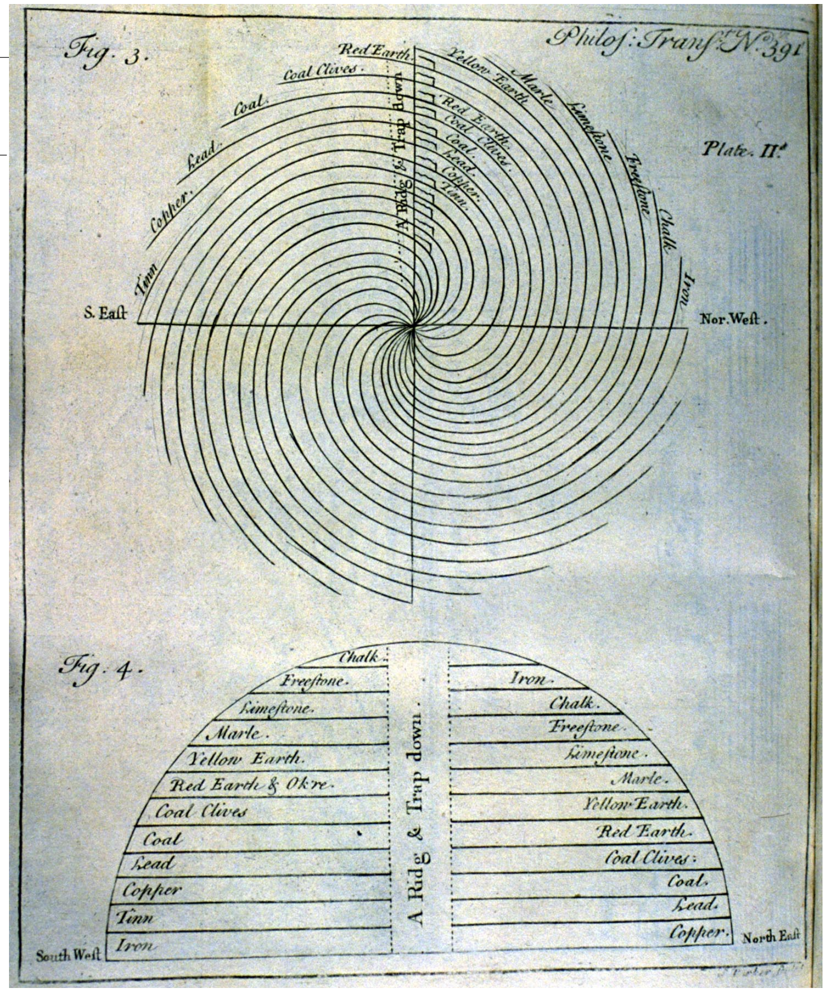

FIGURE 201. Strachey global section.

Description. Above: Equatorial section, looking up northward from a position in the south beneath the globe. Below:

Both Robinson and Strachey privileged the evidence of English mining knowledge as they developed their Theories. Strachey is sometimes regarded as a factual observer unrelated to Theories of the Earth, in contrast to the Theory of Robinson which displays characteristics conventionally regarded as diagnostic of the mentality of Theories of the Earth: a mystical blend of cosmology, theology, and esoteric philosophy, even the denial of the organic origin of fossils. Yet the greatest contrast between them is that *because of these conventional characteristics* (and by deploying hexameral idiom in opposition to the nondirectionalist Theory of Woodward) Robinson interpreted the structure of the Earth as the result of a temporal series of successive events. That Robinson did so and Strachey did not undermines characterizations of Theories of the Earth as an inherently ahistorical genre of thought.

In several important articles John Fuller shows that Strachey's diagrams inspired the stratigraphical techniques of William Smith, often hailed as the founder of the geological principle that strata may be correlated on the basis of their fossils. Smith prepared a global section of his own (reproduced by Fuller), although he attributed the regular superposition of the strata to the deluge instead of the creation.[69] In one important respect the examples of Smith (and Strachey) are typical of early members of the Geological Society of London such as William Conybeare, who often engaged the problem of unravelling the structural relations of strata while respecting an unstated moratorium on raising contentious questions of how the order of the strata disclosed a temporal origin.[70] This departure by English geologists from the Wernerian tradition of geognosy is even more remarkable than their acceptance of the volcanic origin of basalt and the mechanism of plutonic uplift (two views that were adopted by many continental geognosts who nevertheless uniformly agreed that the structural relations of different formations reflects a temporal succession).

[69] See the works by Fuller cited in footnote 68, and John G. C. M. Fuller, *"Strata Smith" and his Stratigraphic Cross Sections, 1819,* with a color poster reproduction of Smith's *Geological Sections*, 1819, at 80% original size (Tulsa, Oklahoma, USA; Bath, United Kingdom: American Association of Petroleum Geologists and The Geological Society of London, 1995). On Smith and Theories of the Earth see (in addition to Fuller) L. R. Cox, "New Light on William Smith and his Work," *Proceedings of the Yorkshire Geological Society* 25 (1942): 1–99; and T. Sheppard, "William Smith: His Maps and Memoirs," *Proceedings of the Yorkshire Geological Society* 19 (1917): 75–253. On Smith and the origin of the principle of identifying strata by the fossils they contain see Joan Mary Eyles, "William Smith: Some Aspects of His Life and Work," in *Toward a History of Geology*, ed. Cecil J. Schneer, Proceedings of the New Hampshire Inter-Disciplinary Conference on the History of Geology, September 7–12, 1967 (Cambridge: MIT Press, 1969), 142–158; Joan Mary Eyles, "William Smith, Sir Joseph Banks, and the French Geologists," in *From Linnaeus to Darwin: Commentaries on the History of Biology and Geology,* ed. Alwyne Wheeler and James H. Price (London: Society for the History of Natural History, 1985), 37–50; Rachel Laudan, "William Smith: Stratigraphy without Palaeontology," *Centaurus* 20 (1976): 210–226; and Martin J. S. Rudwick, "Cuvier and Brongniart, William Smith, and the Reconstruction of Geohistory," *Earth Sciences History* 15 (1996): 25–36.

[70] Rudwick's analysis of an illustration by Conybeare is a typical description of an English emphasis on structure rather than time: "Most of the stratigraphical 'succession,' or series of 'formations' of strata, had been established (with the degree of detail relevant to this story) long *before* the corresponding scenes [i.e., landscape depictions] were first produced. Of course, geologists in the early nineteenth century were well aware in principle that their series of stratigraphical formations was a record of a sequence of periods, but they treated it more often as a *structural* stack of three-dimensional rock masses than as a *temporal* sequence of events in earth history. As late as the 1820s, the sheer novelty of any fully historical reconstruction of the deep past is vividly expressed, for example, in Conybeare's cartoon and doggerel celebrating Buckland's verbal reconstruction of an 'antediluvian' hyena den...." Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992), 226–227.

§ 5. Elevation by Central and Subterranean Fire

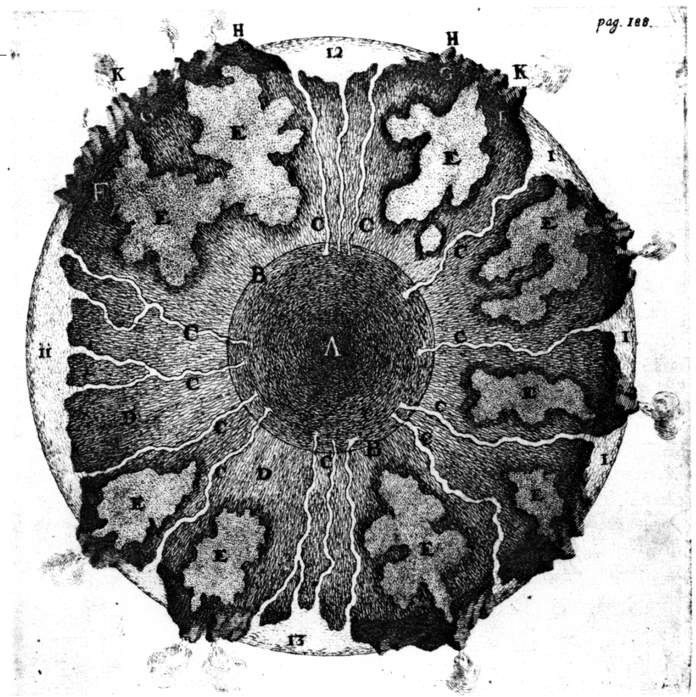

FIGURE 202. Urban Hiarne, *Parasceve* (1712).

In the early eighteenth century, after Descartes, Kircher, Becher, and others, it was by no means unusual for writers such as Urban Hiarne (1641-1724) to envision the interior structure of the Earth as containing a central fire (A), subterranean passages (C) communicating with the seas (I), and vast caverns of air or fire (E) underneath the dry land (H).[71] In the following pages the global sections of Moro, Whitehurst, Erasmus Darwin and Poulett Scrope provide a basis for discussing historical sensibilities and the effects attributed to central and subterranean fires.

[71] Urban Hiärne, *Parasceve* (Stockholm, 1712). Cf. Tore Frängsmyr, *Geologi och skapelsetro: Föreställningar om jordens historia från Hiärne till Bergman*, Lychnos-Bibliotek, Studier och källskrifter utgivna av Lärdomshistoriska Samfundet (Studies and sources published by The Swedish History of Science Society), 26 (Stockholm, Uppsala: Almqvist & Wiksell Boktryckeri AB, 1969).

§ 5-i. Moro's Ultra-Volcanism

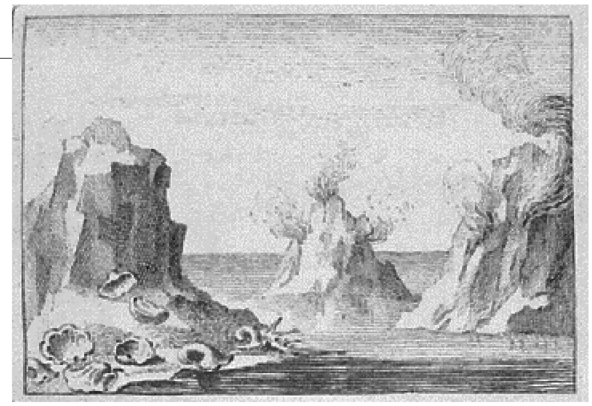

FIGURE 203. Moro, *De Crostacei*, 1750. Title page detail. LH.

Description. Shellfish lie on the shoulders of volcanic mountain islands.

In *De Crostacei* (1740), several decades before William Hamilton's *Observations on Vesuvius* (Chapter 1), the cleric Anton-Lazzaro Moro (1687–1764) proposed that all dry land on the surface of the Earth was elevated by the action of subterranean fire. Moro found evidence to support his views from observation of volcanic strata, the formation of volcanic islands, and the distorted and convoluted layers of mountains. In 1707 a new island near Santorini rose from the Aegean Sea amidst the circle of volcanic islands known as the Cyclades. Moro reflected on this event and on the origin in 1538 near Pozzuoli in Naples of Monte Nuovo.[72] Arguing that Nature always does the same thing in the same way (a principle he regarded as Newtonian but which Steno had renounced in physics as inconsistent with comparative anatomy), Moro came to the conclusion that all mountains are of volcanic origin and that even stratified rocks must originate from volcanic material ejected from vents before or during ancient eruptions.[73]

[72] Anton-Lazzaro Moro, *De Crostacei e degli altri Marini Corpi Che si truovano su' monti Libri Due* (Venice: Appresso Stefano Monti, 1740). Cf. Frank Dawson Adams, *The Birth and Development of the Geological Sciences* (Williams & Wilkins, 1938; reprinted New York: Dover, 1954), 365–372, and Ellenberger, 135–137. A lucid summary of Moro's views is Rappaport, *When Geologists were Historians*, 223–226. For a summary of Moro's views as known in England see P. H. Zollman, "An Extract, by Philip Henry Zollman, Esq; F.R.S. of a Philosophical Account of a new Opinion concerning the Origin of Petrifactions found in the Earth, which has been hitherto ascribed to the universal Deluge; as contained in an Italian Book, intitled *De Crustacei ed altri marini Corpi che se trovano su' Monti* di Anton Lazzaro Moro, Venice, 1740, communicated together with several Remarks, by Dr. Balthasar Ehrhart, Physician in Ordinary at Memmingen, and Member of the *Acad. Nat. Curios*. in High-Dutch at Memmingen, 1745," *Philosophical Transactions of the Royal Society of London* 44 (1746): 163–166.

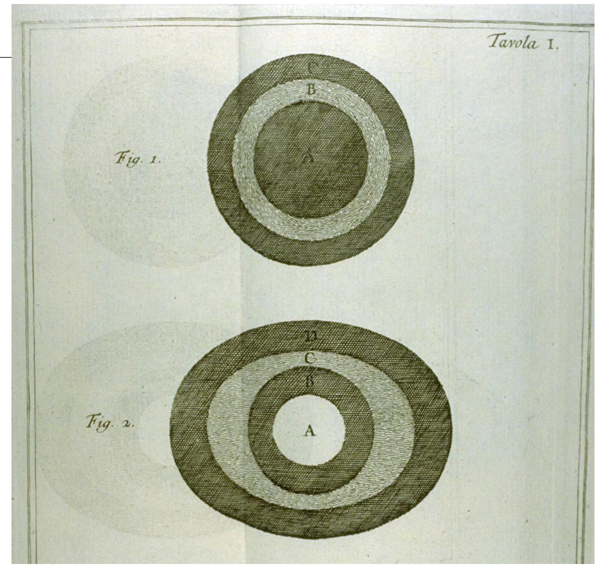

FIGURE 204. Moro, *Tavola I*. Burnetian-style global sections. (*Fig. 3* not shown.)

Moro's account of the globe begins with Burnetian-style diagrams (Figure 204, Figure 205 and Figure 206). Originally the round Earth was completely smooth and water covered the land. Then the unstratified, nonfossiliferous primitive mountains were cast up during the creation week, with the days understood as long periods of time. Beginning on the third day, continuous deposition of ejected volcanic material formed the stratified rocks, making the emergent lands and oceans fertile for life. For Moro, mountains which arose any time thereafter, from beneath stratified rocks, are secondary mountains. To him the Deluge was a miracle outside the scope of investigation, but Moro severely criticized the Theories of Burnet and Woodward for advocating deluge mechanisms that did not account for marine fossils in the mountains.[74] Moro did not cite Steno, and if his classification correlated mountain types with eras of formation, unlike Steno he fixed the initial origin of both types within the creation week and employed a volcanic method of formation instead of aqueous deposition.

[73] Zollman summarized his principal thesis as: "That marine Animals and Productions (for Instance, Shells, &c) which are now found in high Mountains, were first generated in the Sea: But when those Mountains were raised, by subterraneous Fire, above the Surface of the Sea, were petrified so as they now appear."

[74] Zollman: "Having in the first Part formed the State of the Question, he examines the Systems of Burnet and Woodward, almost generally received by the Learned, though the former does not make any express Mention of Petrifaction. He refutes their Opinions about the Deluge, and of its being the Cause of Petrifactions. He lays down for a fundamental Maxim, that the Deluge ought to be believed, according to the Scripture, as a Miracle, and not to be proved by natural Rules; from which he proceeds to another; viz. That whoever lays down, for a Foundation, a Principle which does not fit the several Phænomena, builds upon an erroneous Principle." Rappaport describes the efforts of Moro and his readers to reconcile his theory with scripture; *When Geologists Were Historians*, 223–226.

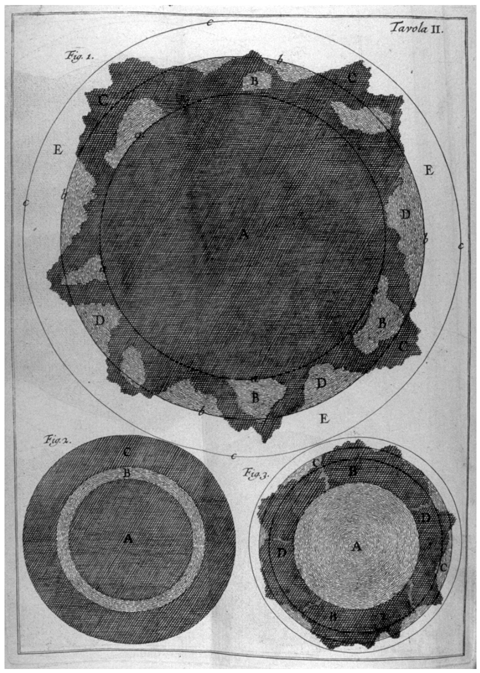

FIGURE 205. Moro *Tavola II*

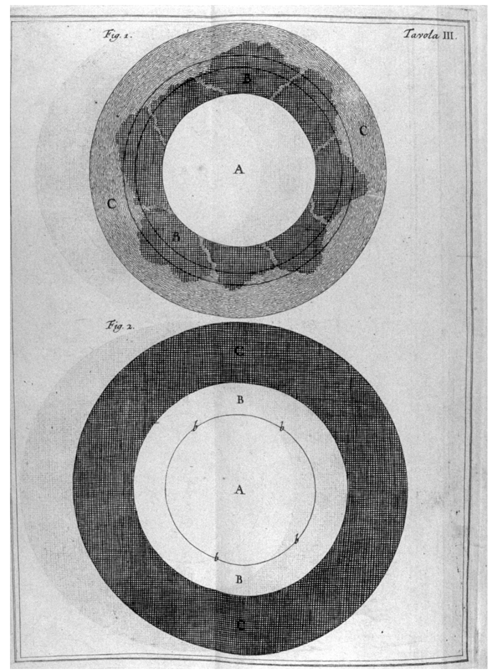

FIGURE 206. Moro, *Tavola III*

Given that the entire surface of the present Earth was derived from volcanic material, according to Moro, the interior of the globe must be the scene of great subterranean fires. As the interior fires burn, fueling the volcanos that produce the Earth's crust, what might fill the resulting spaces emptied by the volcanic material delivered to the surface? Moro thought that if the cavities are not simple vacua there are two possible views, which he illustrated with two global sections.

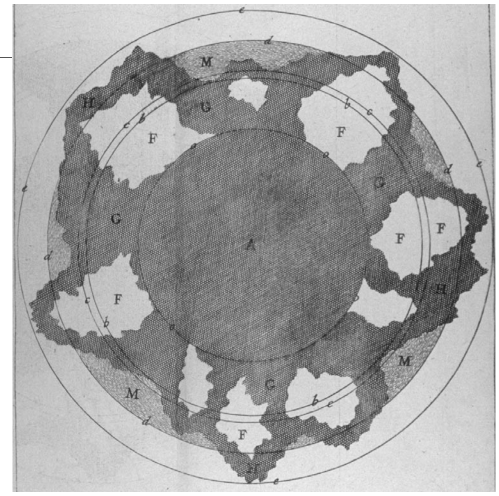

FIGURE 207. Moro, *Tavola VII*. Solid center.

In Moro's first hypothesis, Figure 207, *A* is a fixed and immovable central region. Fires lighted in the exterior region of *A* raise it upward as in *G*, separating dry land (*H*) from the oceans (*M*).[75] The cavities emptied by ejected material are filled with air or gases (*F*).

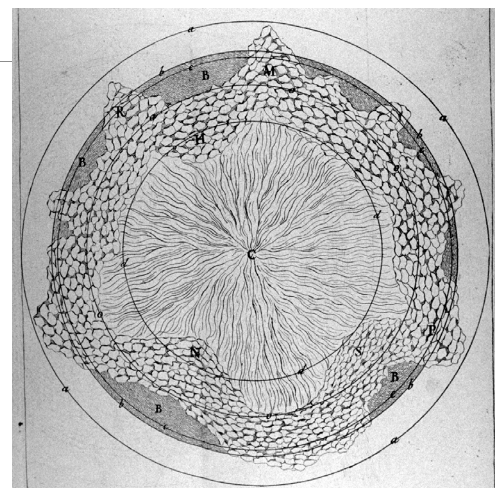

FIGURE 208. Moro, *Tavola VIII*. Central fire.

Moro illustrated another possible interior structure with Figure 208. In this case the crust is thick and irregular (*R-H-M-P-N-S*), surrounding a central fiery fluid (*C*). As the action of the fire elevates one region of the crust another region sinks inward the same amount, much as Hooke had argued. The oceans (*B*) lie between upraised portions of the crust (e.g., *R, M, P*), above the depressed portions (e.g., *H, N, S*).

Moro wrote squarely in the tradition of Theories of the Earth, yet even Oldroyd concedes that it was partially historical in character:

> The superposed strata represented for Moro the chronological sequence of the formation of the Earth, and could give an indication of its past circumstances. Thus, as early as 1740 there was in Moro's work something approaching an historical attitude towards a study of the Earth, despite the fact that it was linked with a par-

[75] This occurred as part of the separation of the dry land and the sea, the work of the third day. "It pleased the great Creator of all things, when the dry land was to appear on the third day according to the sacred account in Genesis, that great subterranean fires should be kindled." Adams, 370.

> ticular *theory*, and also attempted a union with the traditional Judaeo/Christian history of Genesis. Moro, I suggest, was not promulgating a purely 'genetic' scheme. The Earth's exact and particular sequence of volcanic eruptions could not be known *a priori*, even if the general principles of patterning of events (Primary and Secondary) does not seem to arise wholly and directly from the evidence of observations.[76]

There seems no reason not to grant to Theorists such as Hooke or Steno what is conceded in regard to Moro.

§ 5-ii. Whitehurst's Enigma

John Whitehurst was a clock-maker in Derby with a reputation as an innovative instrument maker and an ingenious inventor. As a prominent member of the Lunar Society of Birmingham (like Erasmus Darwin, considered next) he was visited by international guests such as Benjamin Franklin and Faujas St. Fond.[77] His Theory of the Earth was published in three versions, each heavily illustrated.[78] Whitehurst moved to London and, the year after publication of the first edition of his Theory, was elected a Fellow of the Royal Society. His geological fieldwork was highly regarded by nineteenth-century geologists such as Fitton, Conybeare, Lyell, and Geikie.[79] A point of major irritation to them was that Whitehurst presented his

[76] Oldroyd, *"Historicism"*, 196–197.

[77] After visiting Whitehurst in 1758, Franklin wrote Whitehurst that "Your new Theory of the Earth is very sensible. . . ." Schofield, *Lunar Society*, 25, citing a letter dated 27 June 1763, in the mss. Collection, Yale University Library.

[78] Whitehurst's Theory was published in three editions (1778, 1786, and 1792), each with additions and enlargements but little revision to pre-existing text. John Whitehurst, *An Inquiry into the Original State and Formation of the Earth: Deduced from Facts and the Laws of Nature* (London: Printed for the author, by J. Cooper, 1778); *John Whitehurst, An Inquiry into the Original State and Formation of the Earth; Deduced from Facts and the Laws of Nature. The Second Edition, Considerably Enlarged, and Illustrated with Plates* (London: Printed for W. Bent, Pater-Noster Row, 1786), John Whitehurst, *An Inquiry into the Original State and Formation of the Earth* (London: Printed for W. Bent, 1792). Quotations are from the 1786 edition, which is conveniently accessible as a facsimile reprint in the History of Geology Series published by Ayer Publishing and Arno Press. Figures are reproduced from the first edition, and are numbered differently in subsequent editions (which also contain additional plates). Important studies of Whitehurst's Theory include John Challinor, "From Whitehurst's *Inquiry* to Farey's *Derbyshire*," *Transactions of the North Staffordshire Field Club* 81 (1947): 52–88; Maxwell Craven, *John Whitehurst of Derby: Clockmaker & Scientist, 1713–1788* (Derbyshire, England: Mayfield Books, 1996); and Robert E. Schofield, *The Lunar Society of Birmingham: A Social History of Provincial Science and Industry in Eighteenth-Century England* (Oxford: Clarendon Press, 1963).

careful and accurate descriptions of the strata around Derbyshire in the context of a cosmogonic Theory of the Earth clothed in hexameral idiom (even including global sections; Figure 210 and Figure 209).

Whitehurst utilized the hexameral account as one component of an authoritative *prisca sapienta* tradition. For example, he agreed that the Earth was originally "without form and void," and that the Sun became visible "in the firmament" only after the atmosphere became transparent, "which seems to corroborate the scripture account."[80] His deistic friends in the Lunar Society of Birmingham were not impressed, as a letter from Josiah Wedgwood illustrates:

> I have read Mr. Whitehursts book to the appendix by which I have been very much pleas'd & edified, but am fully persuaded his manuscript has undergone as many alterations since its first formation by the free philosopher of Derby as his world has suffer'd by earthquakes & inundations, & I should now call it, An inquiry into &c—fully proving against all infidels and gainsayers the truth & inspiration of the mosaic account of the creation, the flood & its various effects.— I own myself astonish'd beyond all measure at the labour'd & repeated efforts to bring in & justify the mosaic account beyond all rhime or reason & were I not fuly convinc'd of my friends own steady belief in Moses & the prophets his over officious zeal in this instance would almost make me doubt the reality of his faith.[81]

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79 According to Challinor, "Whitehurst's statement on stratification in Derbyshire has been quoted or referred to by Fitton, Geikie, Conybeare, Lyell, and Stebbing, among others; his hypothesis of the volcanic origin of Derbyshire toadstone, reached four years later than, but independent of, Desmarest, was a significant contribution to geology...." Challinor comments that his "elucidation of the Derbyshire succession served to establish the principle of regular superposition of Strata,' he recognized the possibility of igneous intrusion, and his 'correct record of contact metamorphism . . . must be one of the first notices of this phenomenon.'" Cf. Schofield, *Lunar Society*, 179. Whitehurst commented: "It was my intention to have deposited specimens of each stratum, with its productions, in the British Museum, arranged in the same order upon each other, as they are in the earth; being persuaded that such a plan would convey a more perfect idea of Subterraneous Geography, and of the various bodies contained in the earth, than words or lines can possibly express: and though I have not hitherto been able to complete this design, yet I am still in hopes of doing it some future day." Whitehurst, *An Inquiry* (1786), 131.

80 Whitehurst, *An Inquiry* (1786), 16, 36. Whitehurst summarized (p. 39): "Having thus endeavoured to trace the operations of nature in forming the chaos into an habitable world; we cannot pass over in silence, the great analogy which prevails between the Mosaic account of the creation, and the result of the preceding deductions: for the same series of truths which are asserted in the former, are hereby deduced from the laws and operations of nature." Note that in comments such as this Whitehurst employed Newtonian language, so that "deduced" referred to the analysis of causes from phenomena rather than a Cartesian deduction from first principles. Whitehurst set out to (Preface, p. 5) "trace appearances in nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the world, not those by which he might have formed it, had he so pleased." Cf. a similar declaration by Whitehurst on p. 28, and Cotes' preface to Newton's *Principia*, xxviii.

Although Whitehurst retained contact with Lunar Society members after his move to London, there is no need to read his use of hexameral idiom as cynical dissimulation or kow-towing to London sensibilities. There were grounds for deistic appropriation of the *prisca sapienta* tradition, because scripture held a degree of limited authority as an ancient text apart from its purported divine authorship. Whitehurst cited not only scripture, but in the manner of Francis Bacon's essay on *The Wisdom of the Ancients*, which he cited with approval, he invoked a variety of ancient authors and concluded that "the presumption is great, that the Newtonian philosophy was familiarly known in remote antiquity."[82]

The question of the integration of Whitehurst's text is raised not only by his use of hexameral idiom, but also by the global sections juxtaposed with accurate depictions of local strata. Schofield's attempt to excise the Theory of the Earth from the geology is typical: "If this were the whole of Whitehurst's book, it would have little significance, but the appendix, from page 143 to page 190, is so different from the first part that it might well have been written by another person."[83] Yet Whitehurst insisted that his book "is not to be considered as a miscellaneous work, whose parts are independent of each other, but the contrary...."[84] At the critical juncture of the work, the transition from his theory of the original state and formation of the Earth to the description of the Derbyshire strata, Whitehurst again affirmed that the latter were provided as "an illustration of the preceding chapters."[85] This textual integration of the parts is evident from a consideration of the role of subterranean fire in the global sections and the depictions of Derbyshire strata.

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[81] October 1778; quoted in Schofield, *Lunar Society*, 176-177. Whitehurst did receive criticisms from Neptunist Christians, as Schofield reports: "The mosaic orthodoxy of the first part of the text could not blind people to the heterodoxy of the last part and Whitehurst was subjected to the pious vituperations of reverend gentlemen, whom Biblical learning had led to prefer Neptune to Pluto." Schofield, *Lunar Society*, 281. Schofield cites William Richardson, *Transactions of the Royal Irish Academy*, 1806, 249.

[82] Whitehurst, *An Inquiry* (1786)*,* 18, citation of Bacon on p. 19.

[83] Schofield, Lunar Society, 178. Schofield was relying upon Challinor.

[84] Whitehurst, *An Inquiry* (1786)*,* Preface, 6.

[85] Whitehurst, *An Inquiry* (1786)*,* 177.

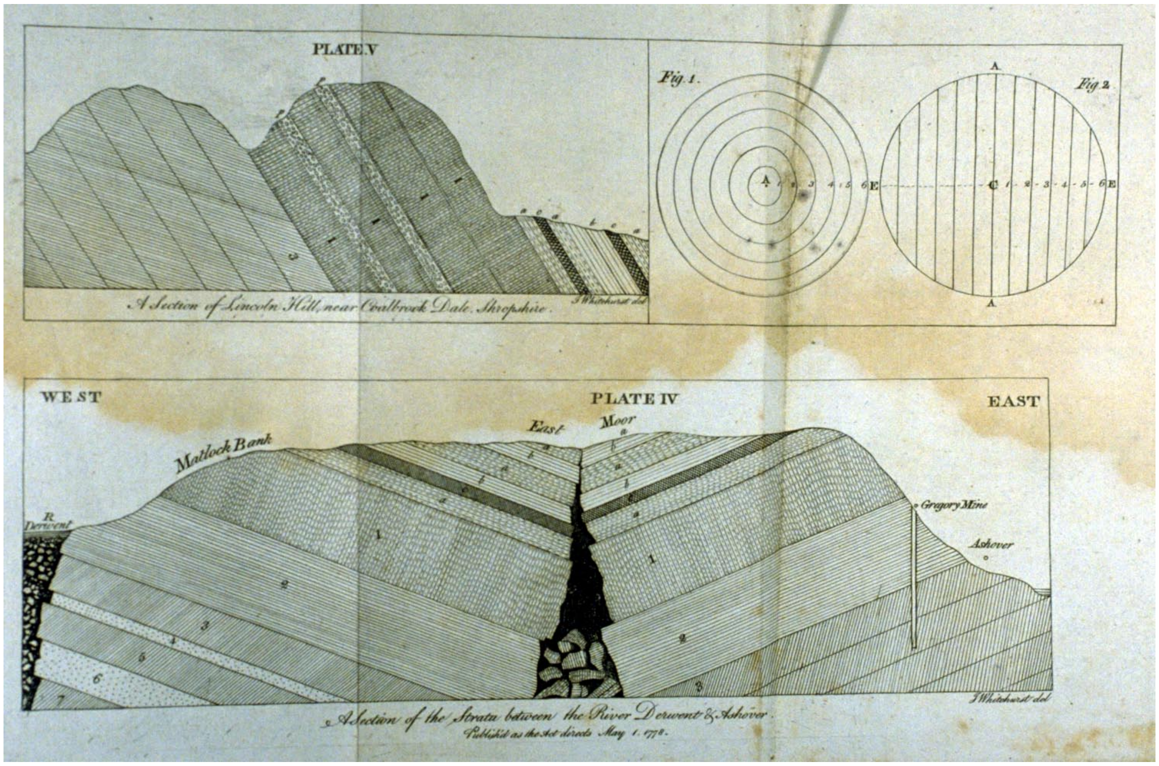

FIGURE 209. Whitehurst, *Plates IV* and *V.* HSCI.

Explanation. Above right. *Fig. 1*: equatorial section. *Fig. 2*: polar section; *A-A* axis, *E-E* equator.

The two global sections in Figure 209 illustrate the original fluidity of the Earth, as strata separated into layers upon the commencement of diurnal motion (which also caused the globe to depart from the figure of a sphere and become an oblate spheroid).[86] The next global section, *Plate IX, Fig. 1* in Figure 210, illustrates the differentiation of the strata after they began to form as depicted in Figure 209. Here two strata of liquid fire appear, the central fire (*G*) and subterranean fire (*F-F*).[87] The fundamental assumptions of originally ordered strata and subterranean fire, established by Whitehurst's Theory of the Earth, provide the causal framework within which he proceeded to historically reconstruct the Derbyshire strata.[88]

[86] Whitehurst, *An Inquiry* (1786), 10–11.
[87] Whitehurst, *An Inquiry* (1786), 117. Whitehurst also discussed this figure in the later part, p. 200.

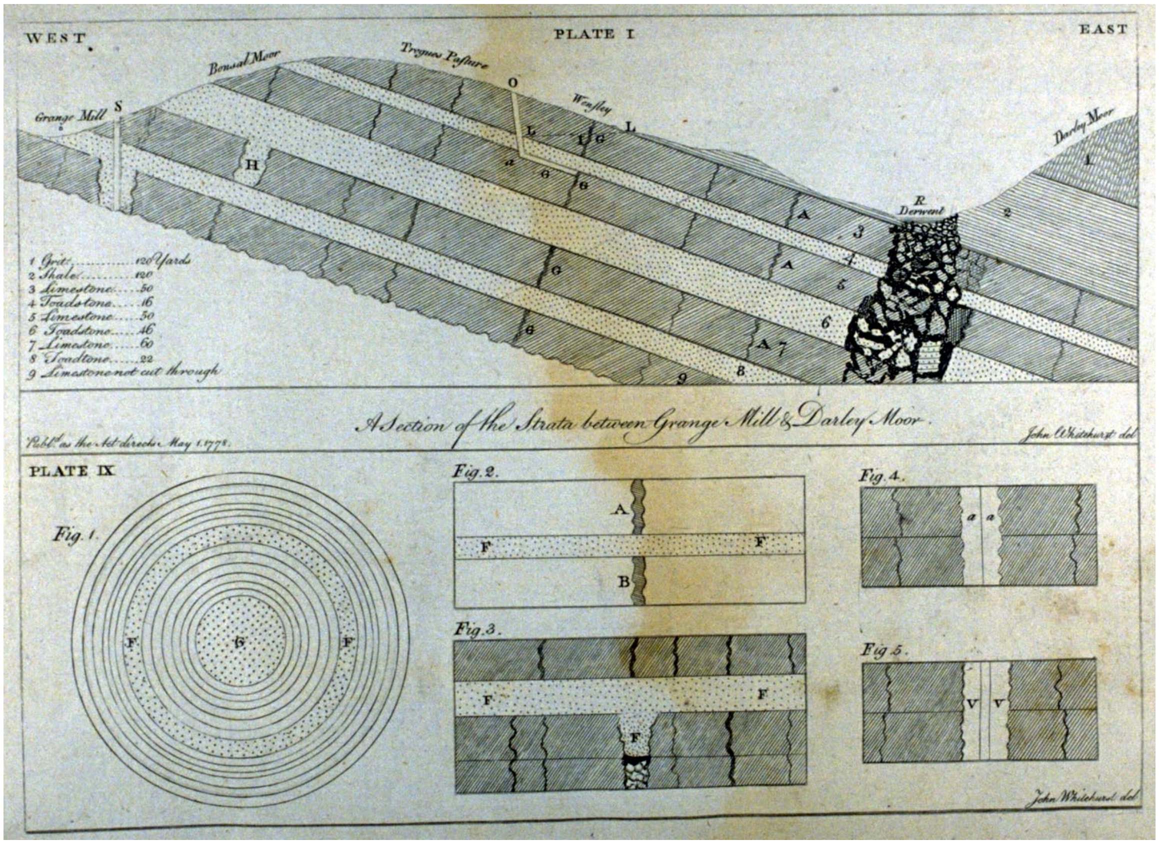

FIGURE 210. Whitehurst, *Plates I* and *IX* (global section). HSCI.

Explanation. *Plate I. A-A-A* and *G-G-G*: fissures in limestone strata. Note the mine near Wensley (top center) which tunnels to fissure *G*. *Fig. 2*: *A-B* is a mineral vein; *F-F* is toadstone.

On the basis of his first part Whitehurst theorized that strata follow each other in a regular succession except where there are disruptions (e.g. elevations, some of which formed mountains) caused by subterranean fires. Speaking of such disruptions in the first part he seems almost to echo the sentiments of Burnet:

> these romantic appearances are not the effects of a regular uniform law, but of some tremendous convulsions, which have thus burst its strata, and thrown their fragments into all this confusion and disorder: nay, the very representation of sea and land, upon a geographical chart, seems alone sufficient to establish the truth of such a conjecture.[89]

[88] Whitehurst, *An Inquiry* (1786), 198–199.

To explain the confusion and disorder of the disrupted strata requires historical reconstruction as well as the invocation of causal agency.

Whitehurst inferred from the original state of the strata that fissures within the strata (*Plate I, G-G-G*) formed from an original expansion of the central and subterranean fires. In cases such as that depicted in *Plate IV*, strata of coal and clay were formed "originally incumbent on grit, and were swallowed up by that dreadful convulsion which burst the strata and threw them into all this disorder."[90] Indeed, "all such vallies were originally great gulfs or fissures thus filled up with rubble or fragments of the upper strata."[91] Later, lava rising some distance up through such fissures must have been occasionally blocked by impervious, uniformly-arranged overlying strata. In such cases the lava spread laterally, slightly elevating the surface of the overlying land, filling any pre-existing fissures it crossed top-down (*Plate IX, Fig. 2* and *Fig. 3*). As the lava cooled under the pressure of overlying rock it became toadstone; thus, toadstone is a volcanic production introduced between strata on the occasion of a further disruption of the strata by uplift. Subsequent local convulsions disrupted the strata even more and threw them into their present state of confusion and disorder.[92]

Contrary to Challinor and Schofield, there is no need to resort to divergent mentalities to explain the two parts of Whitehurst's text. Rather, both together comprise his Theory of the Earth, and there is a seamless transition from the initial causal theorizing about the formation of the original strata and the concluding historical reconstructions of the series of events explaining their present configuration. Only by artificially disentangling them can one assert that Theories of the Earth were uniformly nonhistorical. Interrelations between the two parts,

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[89] Whitehurst, *An Inquiry* (1786), 61. In the second part Whitehurst described these events as "violent convulsions" which occurred not as "primary productions of nature" but both long after the creation of the world and nevertheless "anterior to history or tradition." Whitehurst, *An Inquiry* (1786), 179, 189. "mountains are not primary productions of nature, but of a very distant period of time from the creation of the world." Whitehurst, *An Inquiry* (1786), 189.

[90] Whitehurst, *An Inquiry* (1786), 191. Plate IV is discussed on p. 199.

[91] Whitehurst, *An Inquiry* (1786), 189.

[92] Whitehurst, *An Inquiry* (1786), 200–201.

and the relevance of the latter part for geology, suggest a continuity between the textual tradition of Theories of the Earth and the incipient technical tradition of stratigraphical geology. Indeed, like the global sections and the local depictions, the two parts of the work (and the two kinds of traditions) were not merely juxtaposed, but to some degree mutually reinforcing.

§ 5-iii. Erasmus Darwin's Botanic Garden

Although he remained active in the Lunar Society of Birmingham, after his marriage and move to his new wife's home in Derby in 1781 Darwin devoted himself to finishing the didactic poem on botany which he had begun in 1777.[93] Erasmus Darwin's *Botanic Garden* presented a Theory of the Earth in poetry that was indebted to Whitehurst and Hutton and which similarly emphasized the elevation of land by subterranean fires. The first part of the poem, "The Economy of Vegetation," begins with the Goddess of Botany descending to address the nymphs of fire and to explain the origin of the universe and of the habitable Earth. In Section I she explains how Love created the Universe. Section II covers atmospheric phenomena, as well as planets, comets, and the orb of the sun. Section III explains fires at the Earth's center and the operation of volcanic mountains. Section IV explores various luminous phenomena upon the Earth. Section V deals with fire, VI with the steam-engine, VII with

[93] [Erasmus Darwin], *The Botanic Garden, A Poem. In Two Parts. Part I. Containing: The Economy of Vegetation. Part II. The Loves of the Plants. With Philosophical Notes*, 4th ed. (London: Printed for J. Johnson, 1799). See Schofield, *Lunar Society*, 204ff, for a judicious account of the publishing and reception of *The Botanic Garden*. Schofield notes that "by 1799 it had gone through at least five English, one Irish, and one American edition. There was another edition in England in 1809 . . . and still another in 1825. Extracts taken from it were published in London and in New York in 1805; it was translated into French, Portugese, Italian, and German. Its popularity was so great, in fact, that Darwin actually aspired to become Poet Laureate." Its popularity quickly dissipated, however, when Darwin's sympathies for the French Revolution exposed him to satire and parody. Schofield, *Lunar Society*, 208–209. N. Garfinkle, "Science and Religion in England, 1790-1800: The Critical Response to the Work of Erasmus Darwin," *Journal of the History of Ideas* 16 (1955): 376–388, argues that the French Revolution vetoed cosmogonical speculation in England. On Darwin and the dissemination of Linnean botany see Janet Browne, "Botany for Gentlemen: Erasmus Darwin and *The Loves of the Plants*," *Isis* 80 (1989): 593–621. See also Desmond King-Hele, *Doctor of Revolution: The Life and Genius of Erasmus Darwin* (London: Faber & Faber, 1977); Roy S. Porter, "Erasmus Darwin: Doctor of Evolution?," in *History, Humanity and Evolution: Essays for John C. Greene*, ed. James R. Moore (Cambridge: Cambridge University Press, 1989), 39–70; and Maureen McNeil, *Under the Banner of Science: Erasmus Darwin and his Age* (Manchester: Manchester University Press, 1987).

electricity, VIII with vital heat and "the great Egg of Night." There are twelve sections in all, followed by nearly 250 pages of "Additional Notes" which are longer than the poem itself.[94] Darwin wrote that he intended his poetry "to inlist Imagination under the banner of Science"[95]; this aim was fully manifest in the explanatory notes. In an "Apology" inserted at the beginning of the fourth edition, he defended his theoretical bent along with the poetic style of the work.[96] Darwin employed a *prisca sapienta* argument to defend the didactic use of poetic metaphor.[97] Nor did he disdain didactic images: in the 1799 edition Darwin included a didactic global section (Figure 211) to summarize a "Geological Recapitulation" which first appeared in the Dublin 1793 edition, appended to Note XXIV on granite. The fourteen numbered points of the recapitulation are quoted in full in Table 65.[98]

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94 Darwin, *Botanic Garden* (1799), "Additional Notes," pp 249–492.

95 Darwin, *Botanic Garden* (1799), iii.

96 "It may be proper here to apologise for many of the subsequent conjectures on some articles of natural philosophy, as not being supported by accurate investigation or conclusive experiements. Extravagant theories however in those parts of philosophy, where our knowledge is yet imperfect, are not without their use; as they encourage the execution of laborious experiments, or the investigation of ingenious deductions, to confirm or refute them. And since natural objects are allied to each other by many affinities, every kind of theoretic distribution of them adds to our knowledge by developing some of their analogies." Darwin, *Botanic Garden* (1799), xvii.

97 "Many of the important operations of nature were shadowed or allegorized in the heathen <p. xviii> mythology, as the first Cupid springing from the Egg of Night, the marriage of Cupid and Psyche, the Rape of Proserpine, the Congress of Jupiter and Juno, the Death and Resuscitation of Adonis, &c. many of which are ingeniously explained in the works of Bacon, Vol. V. p. 47. 4th Edit. London, 1778. The Egyptians were possessed of many discoveries in philosophy and chemistry before the invention of letters; these were then expressed in hieroglyphic paintings of men and animals; which after the discovery of the alphabet were described and animated by the poets, and became first the deities of Egypt, and afterwards of Greece and Rome. Allusions to those fables were therefore thought proper ornaments to a philosophical poem, and are occasionally introduced either as represented by the poets, or preserved on the numerous gems and medallions of antiquity." Darwin, *Botanic Garden*, xvii–xviii.

98 "For the more easy comprehension of the facts and conjectures concerning the situation and production of the various strata of the earth, I shall here subjoin a supposed section of the globe, but without any attempt to give the proportions of the parts, or the number of them, but only their respective situation over each other, and a geological recapitulation." Darwin, *Botanic Garden* (1799), 378. [Erasmus Darwin], *The Botanic Garden; A Poem, In Two Parts. Part I. Containing the Economy of Vegetation. Part II. The Loves of the Plants. With Philosophical Notes* (Dublin: Printed by J. Moore, 1793); [Erasmus Darwin], *The Botanic Garden, A Poem. In Two Parts. Part I. Containing: The Economy of Vegetation. Part II. The Loves of the Plants. With Philosophical Notes*, 4th ed. (London: Printed for J. Johnson, 1799).

TABLE 65. **Darwin, Geological Recapitulation, 378–381 (1799)**

#	Topic	Description
1	Projection of Earth from the Sun	"1. The earth was projected along with the other primary planets from the sun, which is supposed to be on fire only on its surface, emitting light without much internal heat like a ball of burning camphor."
2	Diurnal motion of the Earth	"2. The rotation of the earth round its axis was occasioned by its greater friction or adhesion to one side of the cavity from which it was ejected; and from this rotation it acquired its spheroidical form. As it cooled in its ascent from the sun its nucleus became harder; and its attendant vapours were condensed, forming the ocean."
3	Original nucleus of the Earth	"3. The masses or mountains of granite, porphyry, basalt, and stones of similar structure, were a part of the original nucleus of the earth; or consist of volcanic productions since formed."
4	Deposition of limestone and other marine formations	"4. On this nucleus of granite and basaltes, thus covered by the ocean, were formed the calcareous beds of lime-stone, marble, chalk, spar, from the exuviae of marine animals; with the flints, or chertz, which accompany them. And were stratified by their having been formed at different and very distant periods of time."
5	Central fires raised the continents, lowered the ocean beds, and...	"5. The whole terraqueous globe was burst by central fires; islands and continents were raised, consisting of granite or lava in some parts, and of lime-stone in others; and great vallies were sunk, into which the ocean retired."
6	Projection of the Moon.	"6. During these central earthquakes the moon was ejected from the earth, causing new tides; and the earth's axis suffered some change in its inclination, and its rotatory motion was retarded."
7	Gradual accumulation of successive terrestrial formations such as coal.	"7. On some parts of these islands and continents of granite or lime-stone were gradually produced extensive morasses from the recrements of vegetables and of land animals; and from these morasses, heated by fermentation, were produced clay, marle, sand-stone, coal, iron, (with the bases of variety of acids;) all which were stratified by their having been formed at different, and very distant periods of time."
8	Fissures also resulted, along with…	"8. In the elevation of the mountains very numerous and deep fissures necessarily were produced. In these fissures many of the metals are formed partly from descending materials, and partly from ascending ones raised in vapour by subterraneous fires. In the fissures of granite or porphyry quartz is formed; in the fissures of lime-stone calcareous spar is produced."
9	the atmosphere.	"9. During these first great volcanic fires it is probable the atmosphere was either produced, or much increased; a process which is perhaps now going on in the moon; Mr. Herschell having discovered a volcanic crater three miles broad burning on her disk."

TABLE 65. **Darwin, Geological Recapitulation, 378–381 (1799)**

#	Topic	Description
10	Boulders, gravel descend from mountains tops.	"10. The summits of the new mountains were cracked into innumerable lozenges by the cold dews or snows falling upon them when red hot. From these summits, which were then twice as high as at present, cubes and lozenges of granite, and basalt, and quartz in some countries, and of marble and flints in others, descended gradually into the valleys, and were rolled together in the beds of rivers, (which were then so large as to occupy the whole valleys, which they now only intersect;) and produced the great beds of gravel, of which many valleys consist."
11	Earthquakes from subterranean fermentation (less severe than earlier ones from central fire)	"11. In several parts of the earth's surface subsequent earthquakes, from the fermentation of morrases, have at different periods of time deranged the position of the matters above described. Hence the gravel, which was before in the beds of rivers, has in some places been raised into mountains, along with clay and coal strata which were formed from morasses and washed down from eminences into the beds of rivers or the neighbouring seas, and in part raised again with gravel or marine shells over them; but this has only obtained in few places compared with the general distribution of such materials. Hence there seem to have existed two sources of earthquakes, which have occurred at great distance of time from each other; one from the granite beds in central parts of the earth, and the other from the morasses on its surface. All the subsequent earthquakes and volcanoes of modern days compared with these are of small extent and insignificant effect."
12	Sandstone	"12. Besides the argillaceous sand-stone produced from morasses, which is stratified with clay, and coal, and iron, other great beds of siliceous sand have been formed in the sea by the combination of an unknown acid from morasses, and the calcareous matters of the ocean."
13	Steam rises through fissures from great depths	"13. The warm waters which are found in many countries, are owing to steam arising from great depths through the fissures of lime-stone or lava, elevated by subterranean fires, and condensed between the strata of the hills over them; and not from any decomposition of pyrites or manganese near the surface of the earth."
14	Basalt columns	"14. The columns of basaltes have been raised by the congelation or expansion of granite beds in the act of cooling from their semi-vitreous fusion."

In the beginning, according to Darwin, the Earth was projected from the Sun along with the other planets (Table 65, #1). Shortly thereafter it acquired its rotation (Table 65, #2) and began to cool, with vapors condensing to form a global ocean. Granite is thus part of the initial nucleus of the Earth (Table 65, #3; represented by the granite core in Darwin's global section).[99] Beneath the global ocean, over "different and very distant periods of time" the marine strata were laid down (Table 65, #4; represented in the global section by the limetone strata lying on top of the granite nucleus).

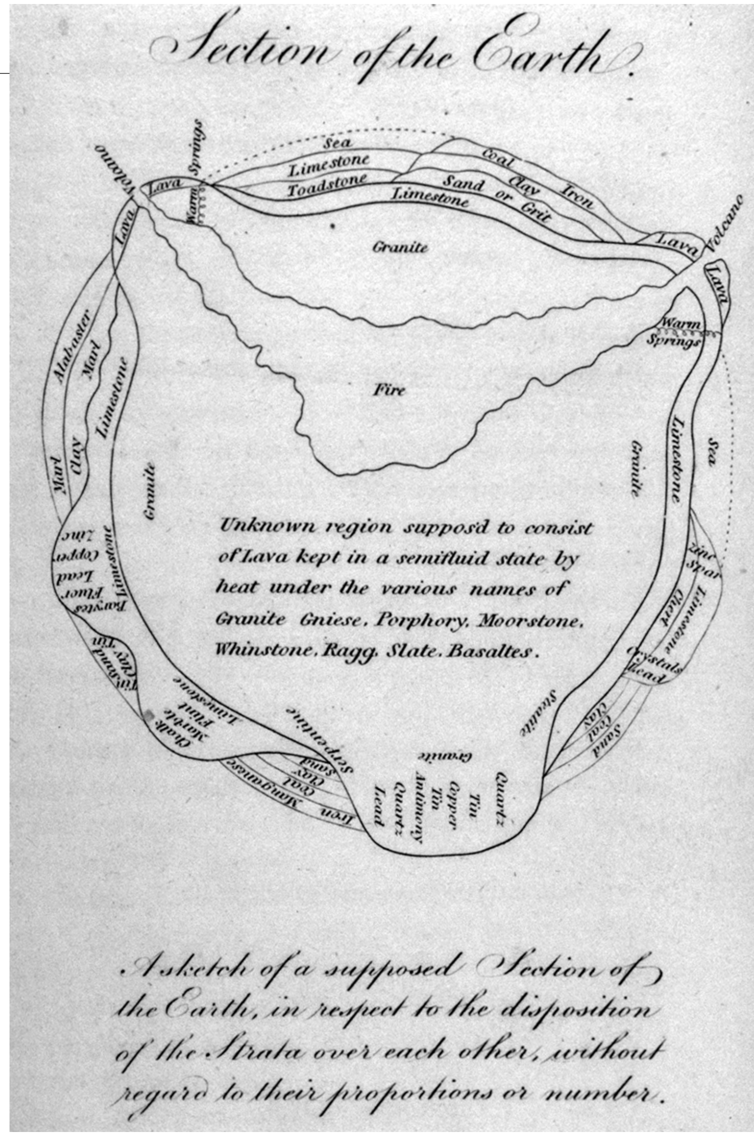


FIGURE 211. Erasmus Darwin, *Botanic Garden* (Dublin, 1799). "Section of the Earth" HSCI.

Caption. Below: "A sketch of a supposed Section of the Earth in respect to the disposition of the Strata over each other, without regard to their proportions or number."

Caption. Center: "Unknown region suppos'd to consist of Lava kept in a semifluid state by heat under the various names of Granite, Gniese, Porphory, Moorstone, Whinstone, Ragg, Slate, Basaltes."

Then came a period when "the whole terraqueous globe was burst by central fires; islands and continents were raised... and great vallies were sunk, into which the ocean retired" (Table 65, #5; represented in the global section by the volcanos top-left and right situated on granite mountains; cf. the nonvolcanic mountain shown below-center). During

[99] This provides Darwin's answer to the options he surveyed in the note on granite: "What is to be thence concluded? Has the granite stratum in very antient times been produced like the present calcareous and siliceous masses, according to the ingenious theory of Dr. Hutton, who says new continents are now forming at the bottom of the sea to rise in their turn, and that thus the terraqueous globe has been, and will be, eternal? Or shall we suppose that this internal heated mass of granite, which forms the nucleus of the earth, was a part of the body of the sun before it was separated by an explosion? Or was the sun originally a planet, inhabited like ours, and a satellite to some other greater sun, which has long been extinguished by diffusion of its light, and around which the present sun continues to revolve, according to a conjecture of the celebrated Mr. Herschell, and which conveys to the mind a most sublime idea of the progressive and increasing excellence of the works of the Creator of all things?" Darwin, *Botanic Garden*, 377–378.

the era of these "central earthquakes" the Moon was ejected from the Earth, just as the Earth previously had been ejected from the Sun (Table 65, #6). Terrestrial formations began to accumulate "at different, and very distant periods of time" (Table 65, #7; e.g., a stratum of coal is shown on the section top right). This same epoch when "the whole terraqueous globe was burst by central fires" produced the atmosphere (Table 65, #9), mountain boulders and gravels (Table 65, #10), and vertical fissures in which metals are found (Table 65, #8; although the fissures themselves are not shown in the section, names of metals are listed in the elevated mountains of granite where the fissures are located).[100]

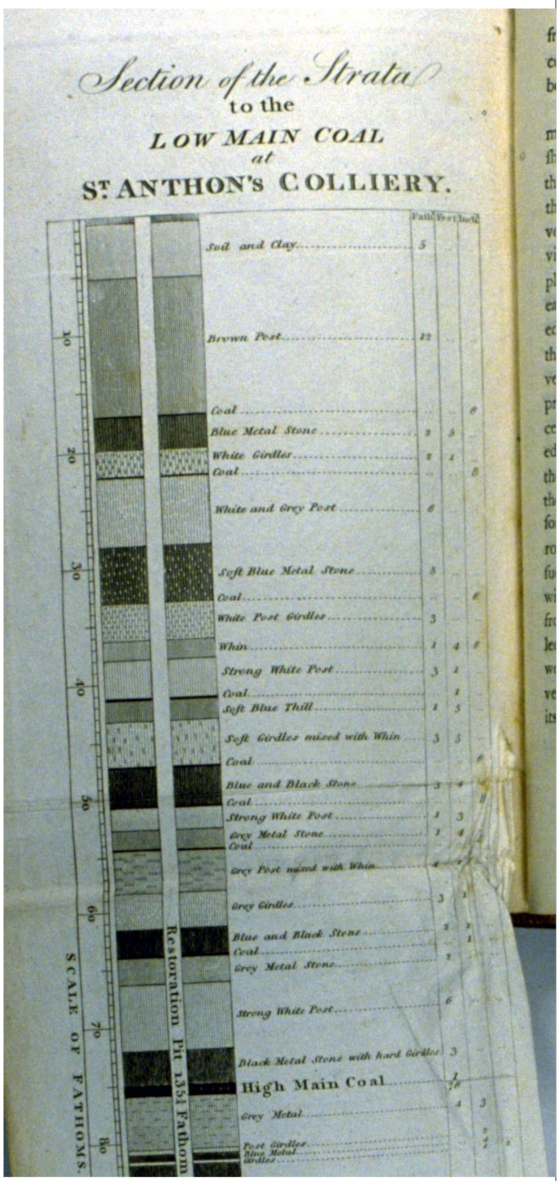
Subsequent earthquakes were much weaker, occurring not as the result of central fires, which substantially abated, but of the fermentation of flammable material within the strata (Table 65, #11; compare Figure 212). Hot springs, however, are still warmed by the central fires, and are not diminished during dry seasons or cooled during long winters (Table 65, #13; in the section hot springs are shown near the volcanos top left and right).[101] Darwin inferred from the lack of oil in coal beds lying between impermeable strata that subterranean steam may alter the coal. Subterranean expansions of vapor also elevated the coal beds and other strata (Table 65, #14) from their ancient position at the bottom of the sea,[102] and in the

[100]Interestingly, although Darwin (a deist) did not explicitly employ hexameral idiom in these notes, his first three points in the recapitulation are adaptable to the idiom of the watery globe of the second day. Next in Darwin's sequence comes the era of central fires, which can be interpreted as correlating with the separation of dry land and seas on the third day (Table 65, #5), and with the origin of the Moon on the fourth (Table 65, #6). I have not yet found a reader who noted this correspondence, but it should make the explicit hexameral idiom of Whitehurst (Darwin's acquaintance) seem less incongruous. That Darwin was a deist is suggested by his correspondence. For example, Darwin and James Keir studied with Albert Reimarus, the son of Hermann Reimarus, a German proponent of natural rather than revealed religion. Years later, Darwin wrote Albert that "Mr. Keir and myself continue in the Religion you taught us, we hold you to be a great Reformed of the Church." Erasmus Darwin, *The Letters of Erasmus Darwin*, ed. Desmond King-Hele (Cambridge: Cambridge University Press, 1981), to Albert Reimarus, April 1769.

[101]Darwin, *Botanic Garden* (1799), 375–382.

[102]Note XXIII, "Coal," 366–376. Darwin described a thin stratum of coal covering hard rock beneath a canal which had no oil and burned without flame like charcoal. Darwin reasoned that to distil the oil from the coal, the coal beds must have been exposed to a considerable degree of heat, and cited the agreement of these deductions with the "ingenious theory of the earth by Dr. Hutton" as published in the first volume of the *Transactions of the Royal Society of Edinburgh*. Darwin, *Botanic Garden*, 369. For Darwin, the heat of the fermentation of vegetable matter with coal beds (not just heat from the central fire) is capable of elevating them together with their overlying strata, even for submarine coal beds lying beneath limestone strata (presumably dry land which subsided beneath the sea). Compare the toadstone stratum in the section top left, not quite continuous with lava, which is intruded between two limestone strata reminiscent of Whitehurst's Theory.

process created vast caverns.[103]



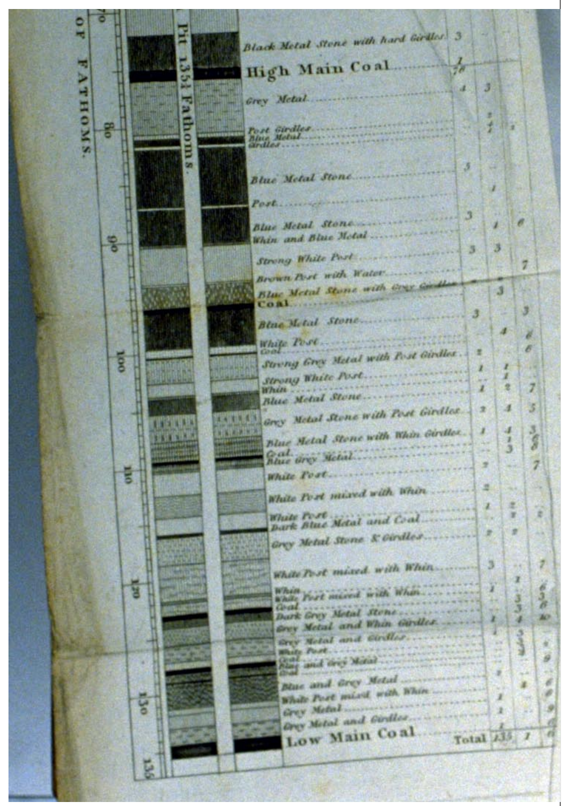


FIGURE 212. Erasmus Darwin, *Botanic Garden*. Colliery section. HSCI.

Caption. Accompanies Note XXIII, "Coal," 366–376, to Canto II., l. 349:
"Hence sable Coal his massy couch extends,
And stars of gold the sparkling Pyrite blends."

[103]"I have lately travel'd two days journey into the bowels of the earth, with three most able philosophers [one of whom may have been Whitehurst, as other letters imply], and have seen the Goddess of Minerals naked, as she lay in her inmost bowers, and have made such drawings and measurements of her Divinity-ship, as would much amuse, I had like to have said inform, you...." *Letters of Erasmus Darwin*, p. 43, to Josiah Wedgwood, 2 July 1767, regarding caverns in Derbyshire. King-Hele notes correspondences between Darwin's text and Coleridge's land of Xanadu in "Kubla Khan." King-Hele, *Doctor of Revolution*, 269-270.

§ 5-iv. Scrope's Vulcanist Cosmogony

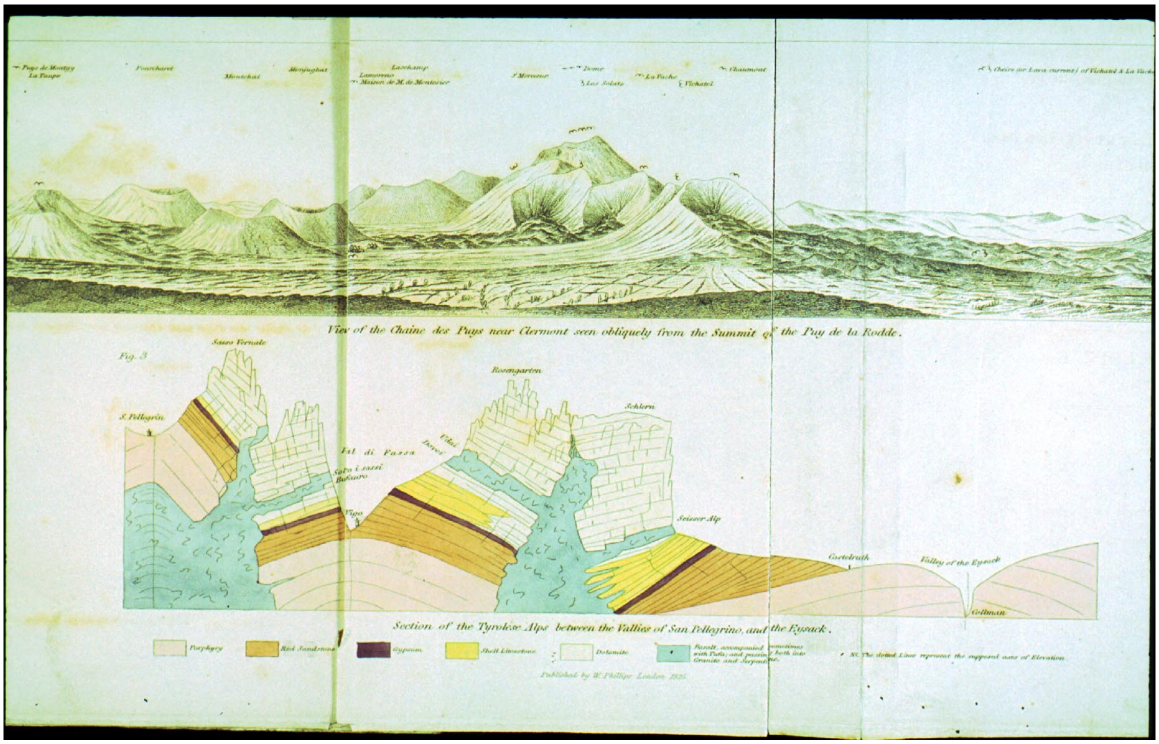


FIGURE 213. Scrope. Volcanos of central France, colored section. HSCI.

George Julius Duncombe Poulett Scrope (1797–1876) opened his most-often remembered work, *Memoir on the Geology of Central France* (1827) with a diatribe against Theories of the Earth, particularly those of a catastrophic nature:[104]

> Towards the end of the last century, men of science became convinced of the futility of those crude and fanciful speculations on the original state of the earth, in which cabinet geologists had for some time indulged; and justly perceived that the only sure road to the true history of our planet lies in a minute and practical study

[104]George Julius Duncombe Poulett Scrope, *Memoir on the Geology of Central France; Including the Volcanic Formations of Auvergne, the Velay, and the Vivarais*, vol. 2 (London: Longman, Rees, Orme, Brown, and Green, 1827); later enlarged as George Poulett Scrope, *The Geology and Extinct Volcanos of Central France, Second edition, enlarged and improved* (London: John Murray, 1858). An excellent study of Scrope and Lyell is Martin J. S. Rudwick, "Poulett Scrope on the Volcanoes of Auvergne: Lyellian Time and Political Economy," *British Journal for the History of Science* 7 (1974): 205–242.

> of those portions of its surface which are open to our examination, and in their comparison with the results of those changes and operations which the ever-active hand of Nature is still carrying on upon that surface.[105]

Promulgating a rhetoric of impartial objectivity, Scrope claimed that he relied on no second-hand textual reports, nor on any pre-conceived theories, but only on what he observed in the field in central France:

> I fortunately entered upon the examination of the great geological features which distinguish this country... wholly uninfluenced by any previously formed opinions on the district before me; having laid down and adhered to a resolution not to open any author who had written on the subject, until I had made myself sufficiently acquainted with it to be able to decide on the degree of credit to which his remarks were entitled. I was, in short, thoroughly determined to form an opinion exclusively my own; and to this end to see with my own eyes, verify every fact myself, and neither take up with the remarks or conclusions of any other observer.[106]

Given such claims it comes as rather a shock to discover that Scrope himself wrote a Theory of the Earth published the previous year, or to read a few pages later that the current book describes observations on which the earlier text was based to the extent that it "may be partly considered an appendix, or *piece justificative*," of the theory![107] Indeed, *Considerations on Volcanos... Leading to the Establishment of a New Theory of the Earth* (1825) is the most frequently-cited source in notes throughout the *Memoir on the Geology of Central France*.[108]

Indeed, Scrope's Theory does not fit conventional characterizations of the tradition, but if Scrope himself referred to the work (or part of the work) as a Theory of the Earth, then presumably something is wrong with the conventional characterization. Scrope argued that The-

[105] Poulett Scrope, *Geology*, 1827, v.

[106] Poulett Scrope, *Geology*, 1826, viii.

[107] Poulett Scrope, *Geology*, 1826, x. The earlier text includes the phrase "Theory of the Earth" in its title: George Julius Duncombe Poulett Scrope, *Considerations on Volcanos, The Probable Causes of Their Phenomena, the Laws which Determine their March, the Disposition of their Products, and their Connexion with the Present State and Past History of the Globe; Leading to the Establishment of a New Theory of the Earth* (London: Printed and published by W. Phillips, 1825).

[108] *Considerations on Volcanos* is cited on pages 6, 42, 45, 49, 54, 56, 62, 64, 82, 86, 95, 99, 103, 104, 109, 110, 138, 147, 149, 152, 166, and 167 of the *Memoir*.

orists should invoke longer periods of time rather than catastrophes and cataclysms.[109] Theories of the Earth are "confessedly imperfect," he conceded, and he offered his own as a "rough draft" or "conjectural rough sketch."[110] He argued for an actualistic methodology, emphasizing the need to rely only on known causes now in operation.[111] He was adamantly opposed to catastrophism, but he was not a Huttonian.[112] Rudwick characterizes Scrope as a deist, and regards his theological perspective as constitutive of his views.[113] But unlike both Hutton and Lyell, Scrope was a directionalist.[114] Scrope outlined the causal part of his Theory in chapter 11, "Origin of the Strata composing the surface of the Globe, involving a Theory of the Earth."

Scrope's initial cosmogonic problem was to explain the origin of the large-grain granite nucleus of the globe. Perhaps the globe began as a comet (rather than a piece of the Sun, as Darwin had it), expanding or vaporizing because of its great heat and the low pressure of space. As the globe settled into an orbit it began to cool down beneath its "aeriform enve-

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[109]"As the idea imparted by the term Cataclysm, Catastrophe, or Revolution, is extremely vague, and may comprehend any thing you choose to imagine, it answers for the time very well as an explanation; that is, it stops further inquiry. But it has also the disadvantage of effectually stopping the advance of the science, by involving it in obscurity and confusion." Poulett Scrope, *Considerations on Volcanos,* iv. Scrope's famous passage about time (*Memoir,* p. 165) is quoted in footnote 36 on page 22.

[110]Poulett Scrope, *Considerations on Volcanos,* vii, 227. A "complete theory of the earth," Scrope confessed, "is difficult to frame on a satisfactory basis" given "the present imperfect state of our chemical knowledge," 226.

[111]If, however, in lieu of forming guesses as to what may have been the possible causes and nature of these changes, we pursue that which I conceive the only legitimate path of geological inquiry, and begin by examining the laws of nature which are actually in force, we cannot but perceive that numerous physical phenomena are going on at this moment on the surface of the globe, by which various changes are produced in its constitution and external characters; changes extremely analogous to those of earlier date, whose nature is the main object of geological inquiry." Poulett Scrope, *Considerations on Volcanos,* iv-v.

[112]"I do not, however, follow the opinion of the Huttonian geologists, that these strata are indurated by the heat transmitted to them from the inferior of the globe. The fact of the occurrence of indurated strata resting on clays and shales, sufficiently disproves this hypothesis." Poulett Scrope, *Considerations on Volcanos,* 222.

[113]Scrope rejected any appeal to supernatural agency, even to explain extraordinary events: "As if any thing could occur that was not caused by some law of nature; or as if we have any right to suppose that these can suffer interruption from any ulterior cause." Poulett Scrope, *Considerations on Volcanos,* 243. This is not to say that actualism required or was even especially prominent in a deistic environment, nor that Scrope was a uniformitarian of the Lyellian sort. In contrast to Lyell, Scrope envisioned episodes of sudden elevation of the ocean beds, attended by consequent violent, oscillating waves which denuded the continents.

[114]"But volcanic eruptions, and exhalations from the subterranean bed of heated crystalline rocks, appear to have diminished by degrees in number and quantity, since the earliest ages of the globe.... At the same time it is extremely probable that the ocean originally possessed a much more elevated temperature than now;....", Poulett Scrope, *Considerations on Volcanos,* 224.

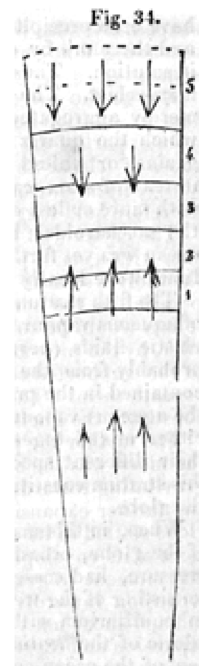
lope," composed of volatile emissions from the granite, while at the same time gravity began to limit the heat expansion of the envelope. To depict the opposing forces of heat expansion and gravitational contraction Scrope employed a balanced gravity column as shown in Figure 214: "This column may be considered as consisting of different strata...."[115] From the opposing processes of heat expansion and gravitational subsidence or precipitation Scrope generated the Primary Formations from the five numbered layers (Table 66). Like contemporary Neptunists such as Jameson, Scrope envisioned a primaeval ocean, intensely hot, carrying silex, carbonates, and other mineral substances in solution.[116] Citing Jameson's *Geognosy*, Scrope suggested that gneiss originated from the precipitation of felspar and quartz, along with mica, under conditions of high pressures.[117]

[115]Poulett Scrope, *Considerations on Volcanos*, 227–230.

[116]Jameson departed from his earlier views and, citing Berzelius and Mitscherlich, proposed something similar (that "our primitive mountains are formed, covered with red hot water," 340) in his notes to the 1827 edition of Cuvier's *Theory of the Earth*. See Note D, "Formation of Primitive Mountains," 335-343, which was substituted for the old Note B, "On Primitive Rocks," deleted for the 1827 edition.

[117]Poulett Scrope, *Considerations on Volcanos*, 230. Cf. Jameson, *Geognosy*, 115.

TABLE 66. Scrope's Columnar Section for Generating Primary Formations

Era	Description (read bottom-to-top)	
Primary formations	5. An equilibrium of the weight of the fluid envelope and the expansive force in this region produces tranquil conditions in which silex, mica, and other matter held in suspension, precipitates into compact beds of rock (e.g., the mica-schist formation). (Precipitation)	 **FIGURE 214.** Scrope, *Fig. 34*, p. 231. Columnar section.
	4. Oceanic strata form in this zone by precipitation and subsidence from the primitive ocean. Suspended particles subside gradually, followed by precipitation of the dissolved minerals as the waters cool. Mica schists and saccharoidal limestones are thus produced. (Precipitation)	
	3. Disintegrated granite loses much of its mica, carried off in suspension by the water. Consolidation of this stratum produces gneiss, felspar, crystals with the remaining quartz and mica, arranged in horizontal planes.	
	2. Disintegrated granite loses its water vapor (which ascends upward, carrying some of the quartz with it in solution). When this granite reconsolidates, it will have a smaller grain than the granite of the lower stratum. (Expansion)	
	1. Disaggregated granite, partially liquefied by vaporization of its contained water, is the lowest stratum, located "immediately above the extreme limit of expansion." This will generate the large-grain granite nucleus. (Expansion)	

Upon this foundation of Primary formations, by degrees, other stratified rocks were deposited to give rise to the Transition formations. After the separation of these five zones, processes of compression and consolidation took over to produce the Secondary formations. All the while, the expansive force of the Earth's interior continued to increase as the outer regions cooled. Eventually the crust yielded, and rocks were violently elevated: "in this manner were produced those original fissures in the primaeval crust of the earth."[118] Minerals precipitated as water exuded into these fissures. Thereafter, during an age of violent rains

[118]Poulett Scrope, *Considerations on Volcanos*, 234.

upon the first continents, the coal strata formed from rotting vegetation under a superheated atmosphere. Subsequently, the temperature of the Earth and its atmosphere diminished further, and animal and vegetable life appeared on the land through a gradual succession of ages. At this point, formations became local, not universal, and record no further general revolutions of the Earth.[119] Scrope's directionalist Theory, replete with occasional violent elevation of continents, is complete.[120]

Scrope's Theory manifests both the variety and the persistence of the tradition of Theories of the Earth. Like Wernerian geognosy, his Theory was more determinedly temporal in outlook than some versions of English structural geology. Nor was his causal and even cosmogonical framework exclusive of geological fieldwork and description. Just as older polemical terms such as catastrophism and Neptunism now seem obsolete, so should polemical contrasts be laid to rest which regard Theories of the Earth and historical geology as mutually-exclusive genres of thought.

[119]"It is therefore evidently needless to imagine unprecedented and extraordinary changes general to the whole surface of the globe for the sake of explaining such alternations which, no doubt, are from time to time taking place in an analogous manner at the bottom of the actual ocean." Poulett Scrope, *Considerations on Volcanos,* 240.

[120]"the superficial destruction of the irregular protuberances of the earth's crust, by the erosive force of water in motion, has gone hand in hand with the accumulation of their fragments in alluvial strata, ever since the epoch of production of the first conglomerate rocks; that it has proceeded generally by a lent and uniform process, gradually diminishing in energy from the beginning to the present day; but occasionally presenting partial crises of excessive turbulence, resulting from accidental combinations of circumstances favourable to the maximum of violence; and particularly the sudden elevation of continental masses—that this process is, for the most part, the same which still operates in the circulation of water, through the atmosphere and ocean, and over the surface of the earth; and finally that the intermittent occurrence of circumstances productive of an excess of disturbance and abrasive energy, as well as the gradual diminution of intensity in the general process, are both of them suppositions warranted by what we already know of the laws which regulate the circulation of water, and of the constitution and active subterranean forces of our planet. Whereas, if this explanation be rejected, we must have recourse to the gratuitous invention of vague and unexampled occurrences, referable to no known law of nature; but which under the specious names of deluges, cataclysms, convulsions, &c. serve merely as convenient cloaks to our ignorance, and solve the difficulty only by the magic of an empty sound." Poulett Scrope, *Considerations on Volcanos,* 240-241.

§ 6. Silberschlag, Caverns, and German Romanticism

When Jules Verne's protagonists journeyed to the center of the Earth (cf. page 373), they also journeyed back in time through the geological epochs reconstructed by Cuvier and the mineralogists. Verne's tale manifests the popularity of a directionalist, historical sense of Earth history in the middle of the nineteenth century. Public fascination with caverns as temporal windows on the Earth's past dramatically increased after the discoveries of large fossil bones, and Johann Esias Silberschlag (1716–1791) provides an example of how the Theories of the Earth of Woodward, Scheuchzer, Catcott, Leibniz, and others were linked with these early developments. Johann Esias was the elder brother of Georg Christoph Silberschlag (1730–1790) who wrote an exegetical study of the origin of the Earth.[121] Both brothers were associated with the *Realschule* in Berlin (Johann Esias as Director) and, as Rupke observes, both combined an interest in apologetics with Pietism.[122] The elder Silberschlag wrote a work on civil hydraulics that was translated into French, and applied his understanding to the cause of the Deluge in the richly illustrated *Geogenie* (1780).[123] Rupke notes that *Geogenie* became widely known, and Silberschlag was elected a member of the *Königliche Preusschische Akademie der Wissenschaften* in Berlin.[124]

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[121]Georg Christoph Silberschlag, *Neue Theorie der Erde; oder, Ausführliche Untersuchung der Ursprünglichen Bildung der Erde, Nach den Berichten der Heiligen Schrift und den Grund-Sätzen der Natur-Lehre und Mathematic Verfasset von Georg Christoph Silberschlag, Mit kupfern* (Berlin: Buchhandlung der Real-schule, ante 1764); cf. number 17 in Table 9 on page 101.

[122]Rupke comments: "Characteristic of the latter [Pietism] was their devotion to secondary school education; Georg Christoph became inspector of the Realschule in Berlin, and his older brother made it to director of the same school. Both were committed to demonstrating the harmony of reason with revelation, of nature with the biblical story of creation and deluge. In doing so they joined a contemporary apologetic movement which was conditioned by Enlightenment rationalism in that it wanted to prove the rationality of Christianity. This form of apologetics was not only represented at the University of Halle, where the brothers Silberschlag had studied theology, but also at Königsberg; here Theodor Christoph Lilienthal wrote his voluminous *Die gute Sache der göttlichen Offenbarung* (1750–1779, sixteen volumes)." Nicolaas A. Rupke, "The Study of Fossils in the Romantic Philosophy of History and Nature," *History of Science* 21 (1983): 392; hereafter Rupke, "Study of Fossils." Throughout this section I am heavily indebted to Rupke's important analysis.

[123]Johann Esaias Silberschlag, *Geogenie oder Erklärung der Mosaischen Erderschaffung nach Physikalischen und Mathematischen Grundsätzen* (Berlin: Im Verlage der Buchhandlung der Realschule, 1780); the History of Science Collections copy is bound with Johann Esaias Silberschlag, *Chronologie der Welt berichtiget durch die heilige Schrift,* Besonders zum Gebrauche der Königlichen Realschule (Berlin, Im Verlage der Buchhandlung der Königl. Realschule, 1783). Silberschalg responded to critics of *Geogenie* with Johann Esaias Silberschlag, *Die Vertheidigte Geogenie* (Berlin: Im Verlag der Buchhandlung der Realschule, 1783).

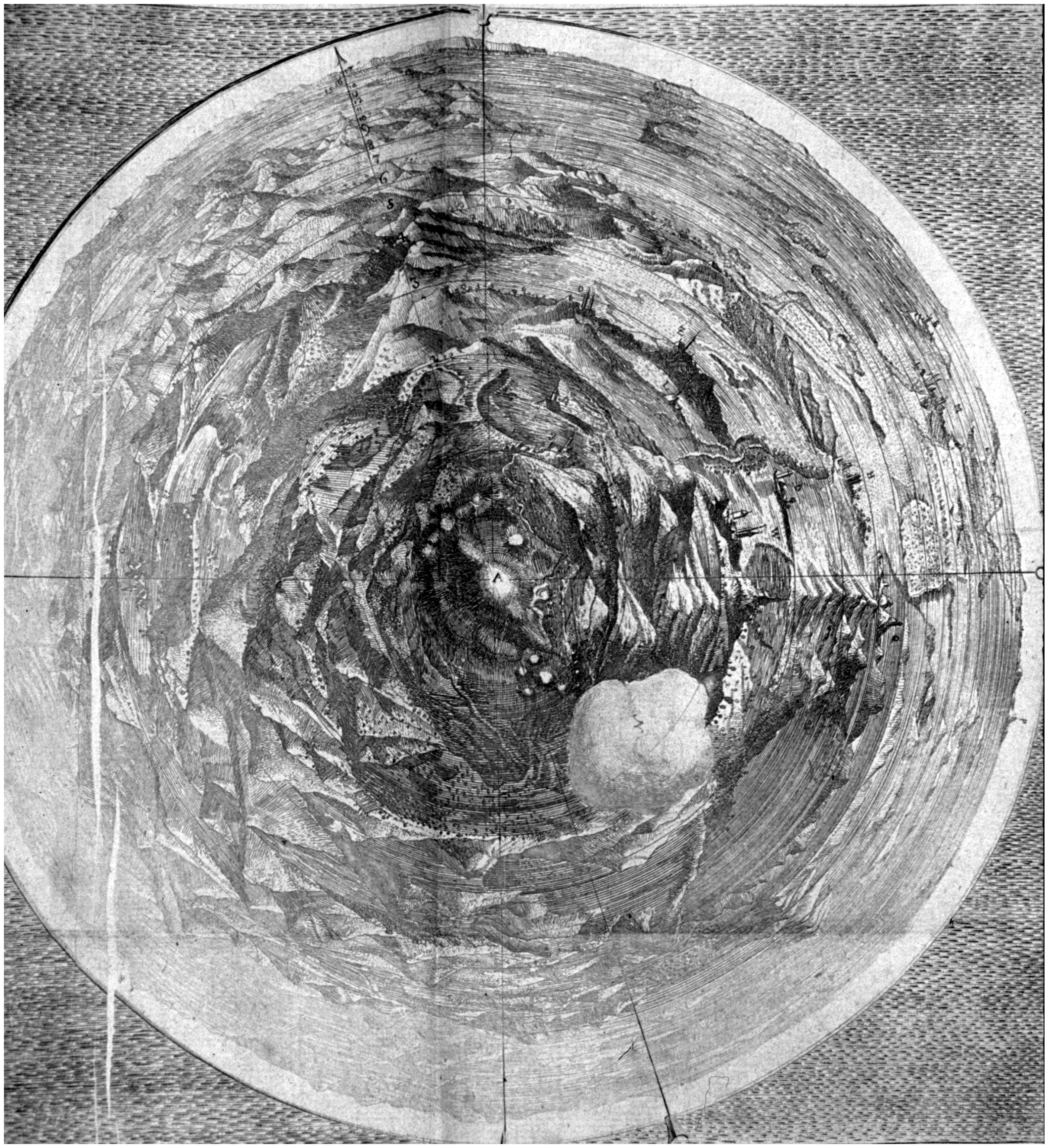


FIGURE 215. Silberschlag, *Geogenie* (1780), *Tab IX*. Panoramic regional view.

Description. Panoramic view as seen looking down from the peak of the Brocten (A), with some of the landscape obscured by a low-lying cloud (N). Concentric circles mark successive miles as indicated on the inclined arow pointing upward and to the left; observe Magdeburg (M), for example, near 2 o'clock and about nine miles away.

[124]Rupke, "Study of Fossils," 393.

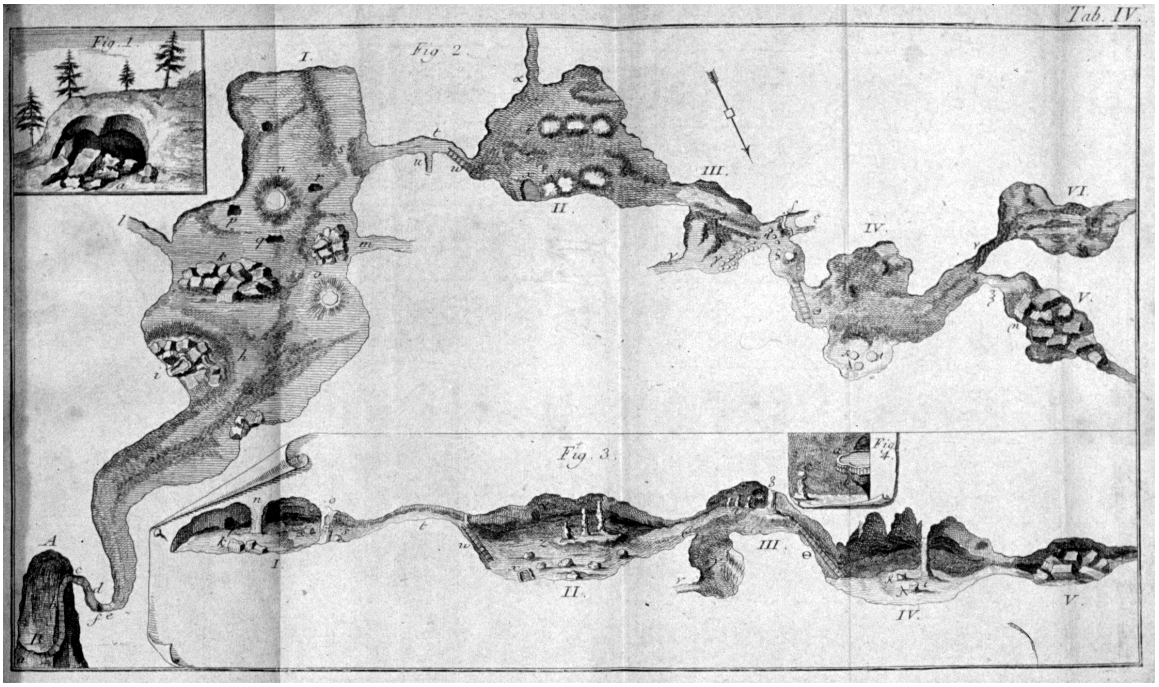


FIGURE 216. Silberschlag, *Geogenie* (1780), *Tab IV,* cave section. LH.

As an example of the variety of Silberschlag's illustrations we may begin with an interesting regional panoramic view from the peak of the Brocten, about seventeen miles in radius (Figure 215). In Figure 216 Silberschlag presented a floorplan (*Fig. 2*) and a section (*Fig. 3*) of the *Baumannshöhle* in the Harz, previously studied by Leibniz. An engraving of the cave and some of the objects discovered within it was prepared by Nicolaus Seelander as the first illustration of the 1749 edition of the *Protogaea*.[125] Leibniz determined that the large bones and teeth he found in such caves (perhaps washed in by the last global deluge) did not belong to any known animals, and suggested that the original animals either had degenerated into

[125]Gottfried Wilhelm Leibniz, *Protogaea sive de prima facie telluris et antiquissimae historiae vestigiis in ipsis naturae monumentis dissertatio ex schedis manuscriptis Viri Illustris in lucem edita a Christiano Ludovico Scheidio* (Göttingen: Sumptibus Ioh. Guil. Schmidii, 1749), *Tab. I.* Latin text with a facing French translation is found in Gottfried Wilhelm Leibniz, *Protogaea: De l'aspect primitif de la terre et des traces d'une histoire très ancienne que renferment les monuments memes de la nature,* trans. Bertrand de Saint-Germain, ed. Jean-Marie Barrande (Toulouse: Presses Universitaires de Mirail, 1993). Silberschlag's *Fig. 2* in Figure 216 has been altered in minor ways from the *Protogaea* illustration, which does not contain a section such as *Fig. 3*. Cf. Roger Ariew, "Leibniz on the Unicorn and Various Other Curiosities," *Early Science and Medicine* 3 (1998): 267–288.

present forms or would be discovered in remote areas.[126] Silberschlag largely shared Leibniz' views, and described in some detail the bones and teeth found in a number of German caves.

Silberschlag emphasized the network of connecting passages between the various open areas (numbered I through VI in Figure 216) within the cavern. It is frequently stated that one of the great unsolved problems of Wernerian geognosy was where the primeval ocean had gone to. This was simply not a problem for those who emphasized the scale of the Earth (cf. Table 70 on page 718). Werner himself appeared content with a phenomenalist approach, *i.e.*, to infer the existence of a primordial ocean from its known effects and leave the search for causes to others. Nor was it a problem for the many other Theorists who emphasized the cavernous character of the crust. For Silberschlag, the existence of such passageways throughout the crust of the Earth suggested that there were communications between the surface and the central abyss. Theorists such as John Woodward, John Hutchinson, Leibniz, and Henri Gautier argued that the Earth contained a watery abyss. Silberschlag similarly envisioned an outward expansion of the crust of the Earth due to centrifugal force at the commencement of its rotation. This centrifugal expansion created both a hollow central abyss and the cavernous network, the latter due to straining and cracking in the crust.

[126]Leibniz, *Protogaea* (1749), sections XXXIV through XXXVII.

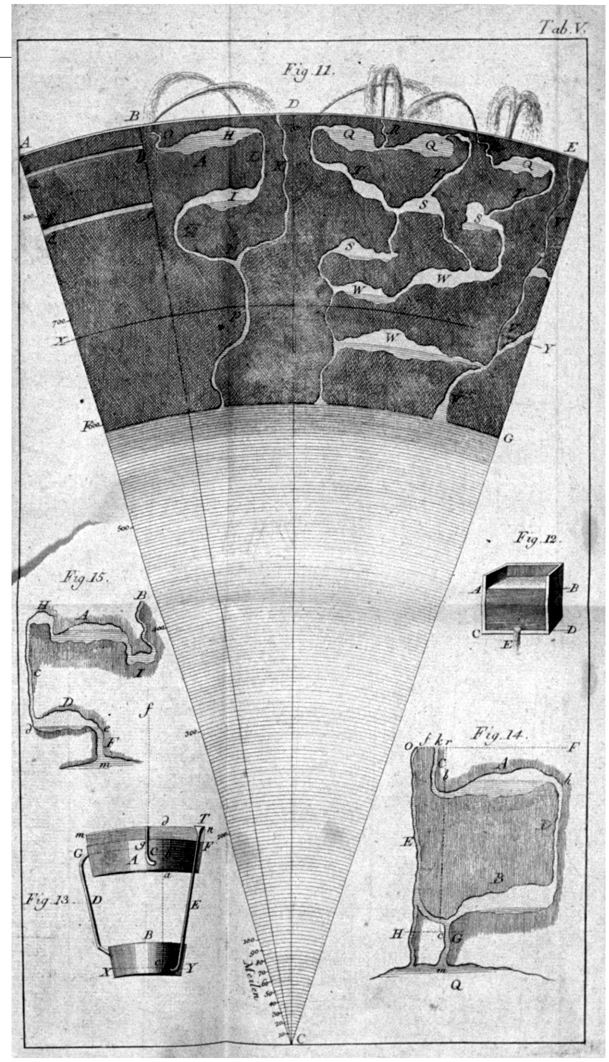


FIGURE 217. Silberschlag, *Geogenie* (1780), *Tab V*

The considerations noted above—hydraulics and communicating passages—combine in Silberschlag's explanation of the Deluge. Taking note of the biblical allusion to the fountains of the deep, Silberschlag showed that, should atmospheric pressure decrease for any reason, water would gush forth from the abyss, rise through the cavernous passages, and emerge as great fountains upon the surface (Figure 217). Silberschlag built several devices to model how changing air pressure may cause water to rise upwards.

Rupke has analyzed the centrality of caves, and their fossil bones, for the development of Romantic notions about the Earth's past:

> Caves occupied a much more central position in geological theory than they do today. They were not regarded as minor and accidental perforations in the uppermost skin of the Earth, as we do regard them now, but they were believed to be pervasive and primordial features, present since the birth of the Earth as a planet, providing essential information as to the manner of its origin.[127]

[127]Rupke, "Study of Fossils," 392.

This, of course, was a perspective shared by many Theorists of the Earth and most hexameral commentators. To this longstanding view, Romantic natural philosophers (and German anatomists studying giant fossil bones) added an important twist:

> Caves were imagined as corridors to the deep recesses of our globe in which the archives of its history were stored, and where the secrets of its past could be discovered, including those of its antediluvial inhabitants, a mighty race of giants and monsters.[128]

Three-quarters of a century before Jules Verne, believing that at least some networks of caverns were primordial, Romantic writers such as Novalis created a literary genre of tales about journeying through subterranean realms, which Rupke deftly surveys.[129]

[128]Rupke, "Study of Fossils," 392.

[129]Rupke, "Study of Fossils," passim. Rupke discusses Ludwig Holberg, *Nicolai Klimii iter subterraneum* (1741), and Novalis, *Bildungsroman Heinrich von Ofterdingen* (1802). Regarding the latter, Rupke comments (p. 395): "It describes the journey of young Heinrich from Eisenach to Augsberg. On the way he encounters an old miner who had been taught by a wise teacher named Werner.... In the company of some fellow travellers and led by the old miner, Heinrich explores a major cave system. In its deep recesses they come upon a recluse, a Count of Hohenzollern, who in his subterranean vault initiates young Heinrich in the true meaning of history." On the relations between Novalis and Werner (with whom Novalis studied) see also Alexander M. Ospovat, "Romanticism and German Geology: Five Students of Abraham Gottlob Werner," *Eighteenth-Century Life* 7 (1982): 105–117; Gerhard Schulz, "Novalis und der Bergbau," *Freiberger Forschungshefte D11* (1955): 242–255; and Fergus Henderson, "Novalis, Schelling and Werner: Approaches to Method in Natural Philosophy," in *Cosmographica et Geographica: Festschrift für Heribert M. Nobis zum 70 Geburtstag,* ed. Bernhard Fritscher and Gerhard Brey, vol. 2, 2 vols., Algorismus: Studien zur Geschichte der Mathematik und der Naturwissenschaften herausgegeben von Menso Folkerts, no. 13 (Münchener Universitätsschriften, München: Institut für Geschichte der Naturwissenschaften, 1994), 143–181.

§ 7. Mineralogists and the Temporal Definition of Formations

§ 7-i. Wallerius: Another Hexameral Mineralogist

Unlike the structural geology of some English practitioners such as Strachey or Smith, eighteenth-century continental mineralogists interpreted the mineralogical formations as originating successively at different times. The unstratified Primary or Primitive formations of granite, basalt, gneiss, and schists often formed the central axis of mountain ranges, were invariably nonfossiliferous, and often crossed with metallic veins of obvious economic value. For mineralogists they crystallized from a primeval fluid, or were deposited by the original ocean as it gradually receded. The *Kurze Klassifikation* (1786) of Abraham Gottlob Werner is discussed in Chapter 1; here we briefly note another important figure: Johan Gottschalk Wallerius, *Tankar om Verldenes* (1776), before considering a later American geognost in some detail.

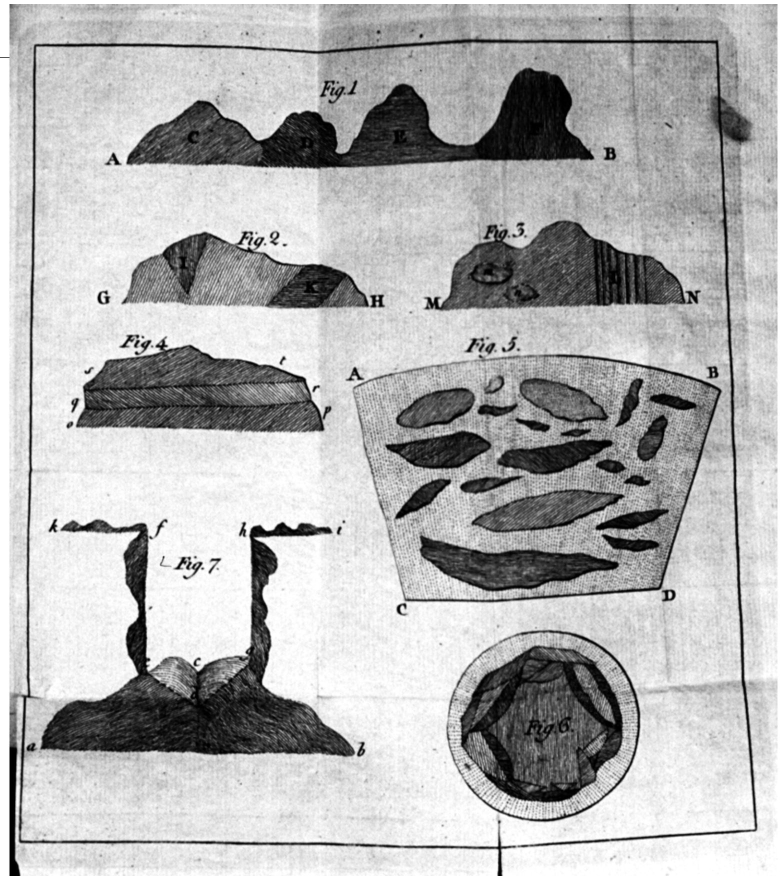


FIGURE 218. Wallerius (1776). On the generation of mountains. Global section (*Fig. 6*).

Explanation. *Fig. 1:* mountains of different types of rocks, A-F. *Fig. 2:* Inclined in all manner of ways, perpendicularly, obliquely, etc. *Fig. 3:* Or enclosed in "glandes" as *m* and *n* in *fig. 3*. Figs. *1-3* are primitive mountains. *Fig. 4:* Collateral layers of rocks in some mountains. *Fig. 6:* Formation of dry land on the third day.

Wallerius' *Tankar om verldenes*, or "Thoughts on the Creation and Change of the World" follows Moses and quotes Genesis 1 systematically and extensively (even on the frontispiece).[130] In the first pages Wallerius situated his discussion as a Theory of the Earth by mentioning Descartes, Burnet, Leibniz, Whiston, Ray, Woodward, Hooke, Moro, Maillet, Bourguet, Buffon, Linnaeus, Élie Bertrand, and van Helmont and the chymists. Wallerius' book is entirely structured as an exercise in mineralogical hexameral exegesis, reaching the events of the third day at its climax.[131] By that time the solid rocks of the Earth coagulated to form dry land, including mountains (*Fig. 6* in Figure 218). Additional excavation occurred as the water ran off the surface of the dry land, filling the ocean beds and retreating via caverns into the interior of the Earth.

[130]Wallerius, Johan Gottschalk. *Tankar om Verldenes: I Synnerhet Jordenes Danande och Ändring*. Stockholm: Tr. hos Henr. Fought, 1776. Cf. Johan Gottschalk Wallerius, *De l'Origine du monde, et De la Terre en Particulier, Ouvrage dans lequel l'Auteur développe ses Principes de Chymie & de Minéralogie, & donne, en quelque manière, un abrégé de tous ses ouvrages,* translated by Jean Baptiste Dubois de Jancigny (Varsovie: et se trouve, à Paris, chez J. Fr. Bastien, 1780).

§ 7-ii. Amos Eaton, Fieldwork, and Wernerian Geognosy

FIGURE 219. Amos Eaton, *Index*, 1818, "Geological Transverse Section." HSCI, LH

Explanation. "A Geological Transverse Section extending from Catskill Mountain to the Atlantic" running roughly along the forty-second parallel from Catskill Mountain and the Hudson River valley (left) to Boston (right). One outcrop of granite is depicted left of center near Hinsdale, above the "RA" of the large label "GRANITE."

For the benefit of students in the Rensselaer School at Troy, near the Hudson River in New York, Amos Eaton (1776-1842) prepared his *Index to the Geology of the Northern States* (1818) as a field guide "to lead you to the very spot where each rock stratum, or imbedded mineral, is to be found."[132] Eaton included a fold-out tranverse section from Boston to "Catskill Mountain." Eighteen numbered strata appear on the plate, from granite underneath, "the lowest known stratum," to alluvial deposits on top.[133] Speaking of the facts

[131]"Vidare, som *tyngds-kraften* år starkast vid ytan af en rund kropp eller sphaere, som Mathematici och Physici bevist, så år klart, det af denna kraften skulle vid jordklotets yta produceras en starkare {\i condensation}; och som *centrifugal kraften* soker tillika drifva kropparna ifrån *medelpuncten*, hvarigenom en stark och hastig praecipitation hindras, så torde håraf kunna flutas, at desse ester sin tyngd nu sig sånkande stenmassor, blisvit, så vida tilråckeligt utrymme det tillåtit, nodgade stanna vid jordens yta til stor del, och derstådes den ena ofver den andra lika som upstaplade, hvaraf jag förmenar de hårdare och mera condenserade bergstråckorna fått sit rum *narmare jordens yta an des medelpunct*. Efter denna grund, at gora min tanka mer begripelig, har jag inbillat mig, efter bemålte bergåmnens praecipitation, kunna forestalla jordklotet i profil, ungefarligen som det ses Fig. 6." *Tankar*, 115-116; Section 21. This passage is translated as follows in the French edition, 223-224: "Mais comme, d'après les démonstrations physiques & mathématiques, la force de gravité agit plus puissamment à la surface, la condensation y a nécessairement été plus grande. D'un autre côté, la force centrifuge, tendant perpétuellement à éloigner les corps du centre ou du diamèter, ces masses ont dû être retardées dans leur précipitation, subsister plus près de la surface, s'y accumuler l'une sur l'autre ou l'une à côté de l'autre, autant que l'espace a pu le permettre. Ainsi il est probable que || le tissu montagneux a été formé plus près de la surface que du centre. Pour mieux faire entendre ma pensée, j'ai voulu représenter l'intérieur de notre globe avec ses masses précipitées & les glèbes des montagnes. Voyez la *fig. 6*." *l'Origine du monde,* 223-224.

arranged by the diagram, Eaton reported "I have travelled more than one thousand miles on foot in collecting them."[134] Despite the rigorous fieldwork invested by Eaton to ascertain geological facts, he cautioned that his section was only an approximation due to difficulties inherent in fieldwork (such as limited access to deeper strata that were frequently obscured underneath accumulated alluvial deposits). For such reasons, Eaton reminded his readers that "A geological section of a country must always be rather a caricature of it, than an exact delineation."[135] Yet if geological sections were not demonstratively certain, nevertheless they could be rigorously and reliably tested:

> To prove the correctness of any one transverse section, several parallel sections ought to be taken. I have examined the ranges transversely between Catskill mountain range and Connecticut river in five places; and find them to be nearly similar, excepting some difference in their respective breadths.[136]

Thus Eaton's regional section served not only to conceptualize and to convey his interpretation of the geological structure of the area, but also as a proxy or virtual witness to certify that Eaton's conclusions derived from observed facts extensively collected and rigorously examined.

[132]Amos Eaton, *An Index to the Geology of the Northern States, with a Transverse Section from Catskill Mountain to the Atlantic* (Leicester, Massachusetts: Printed by Hori Brown, 1818), 3. Hereafter "Eaton, 1818." Two global sections also appear in Amos Eaton, *Geological Textbook for Aiding the Study of North American Geology* (Albany: Websters & Skinners, 1832), HSCI, ~LH. In an excellent study, David Spanagel analyzes Eaton's role in the planning of the Erie Canal; David I. Spanagel, "Chronicles of a Land Etched by God, Water, Fire, Time, and Ice" (Ph.D. Dissertation, Harvard University, 1996).

[133]The location and appearance of each stratum on the plate is described in an accompanying explanation on p. 7. Vertical and horizontal dimensions are drawn to different scales.

[134]Eaton, 1818, 5.

[135]Eaton, 1818, 4. Rivers cut most of the strata transversely as well, facilitating inspection of the strata.

[136]Eaton, 1818, 39.

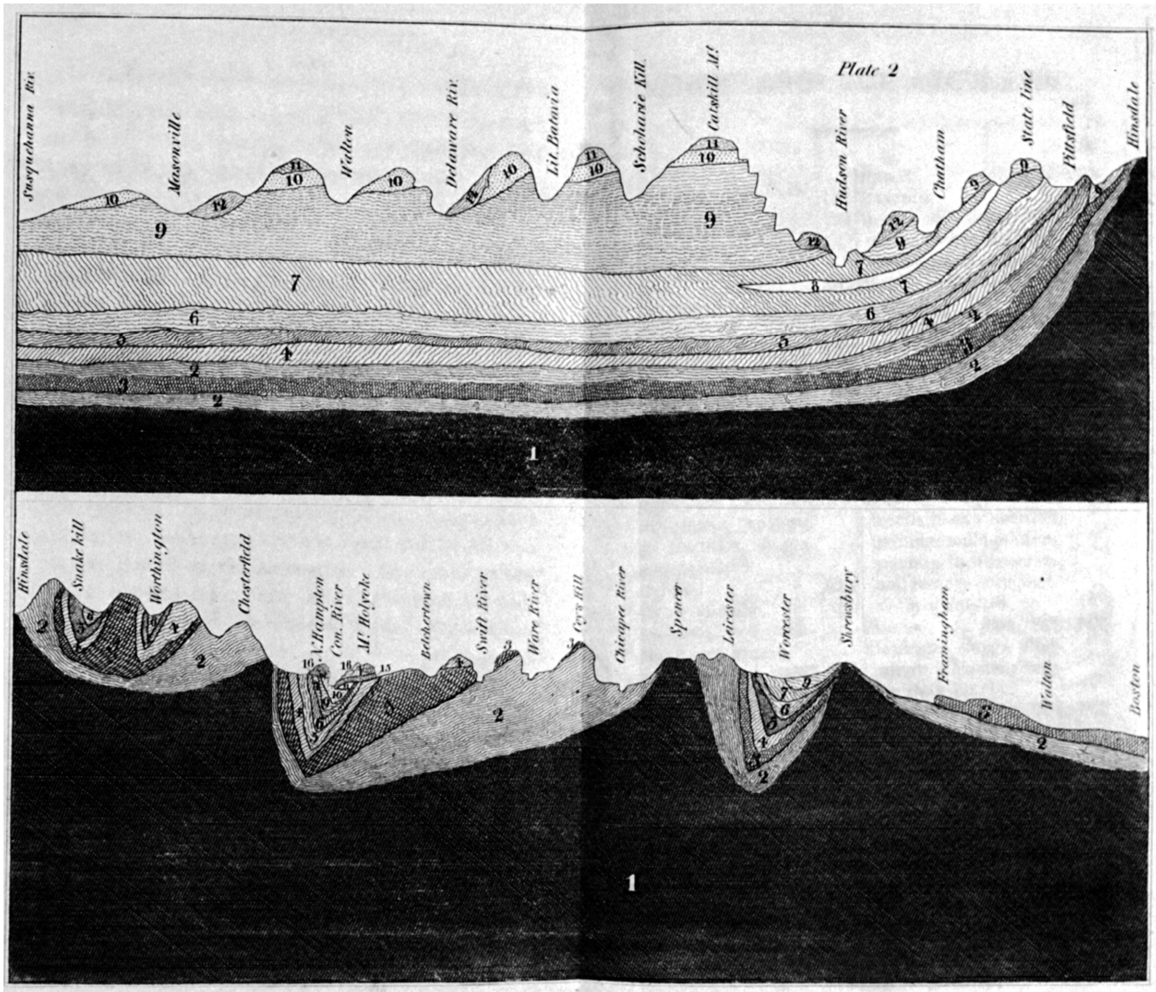


FIGURE 220. Amos Eaton, *Index*, 1820, *Plate 2*, ...

Description. Vertical scale exaggerated (compare with previous section). The lower row continues the upper row, from Susquehanna River (top left) to Boston (lower right). An outcrop of granite near Hinsdale is shown at the right edge of the top row and the left edge of the bottom row. Catskill Mountain, the western terminus of the previous section, is on the top row, right of center, to the west of the Hudson River. LH and HSCI.

A revised and expanded version of the *Index,* with two plates, was published in 1820.[137] In this second edition *Plate 2* provided another transverse section running roughly westward

[137] Amos Eaton, *An Index to the Geology of the Northern States, with Transverse Sections, extending from Susquehanna River to the Atlantic, crossing Catskill Mountains; to which is prefixed a Geological Grammar,* 2d ed. (Troy, N.Y.: Published by Wm. S. Parker, sold by him; Albany: by Websters and Skinners [and six others], 1820). Hereafter, "Eaton, 1820."

from Boston along the forty-second parallel, extending past the Catskill Mountain to the Susquehanna River near Jericho in New York. Again Eaton emphasized the observational basis for his visual representations: "The rocks on the surface are laid down from actual observations..."[138] Eaton anticipated censure for rejecting many strata listed by European geologists: "My reply is a short one—I do not insert them, because I cannot find them."[139] In the preface Eaton insisted that the arrangement of the book was "wholly founded upon my own observations" in Massachusetts, Connecticut, Vermont and New York.

TABLE 67. Eaton's Wernerian Classification and Hexameral Theory (1818)

Class	Day	Description, Examples
Primitive	2	Lowest strata observed if in original positions. Nonfossiliferous. Original horizontality, but often vertical due to later elevation by expansive power. Granite, granular limestone, gneiss, mica-slate, serpentine, quartz, sienite, etc.
Transition		Rest upon primitive strata. Contain marine petrifactions.
Secondary	3	Uppermost regular strata. Contain marine, terrestrial, and freshwater fossils. Red sandstone (sometimes fossiliferous), breccia, compact limestone, gypsum, rocksalt.
Superincumbent		Rest nonconformably on other rocks. In New England, rest on breccia or red sandstone. Always above primitive hornblende rocks, and may include hornblende as a constituent mineral (if so, then are volcanic in origin). Volcanic productions are included in superincumbent class. Basalt, greenstone trap, and amygdaloid.
Alluvial		Loose layers of broken or disintegrated rocks. Gravel, sand, clay, loam.

In 1818 Eaton adopted a Wernerian classification of formations (Table 67). In 1820 he largely presented the theory adopted in 1818 with greater elaboration and confirming detail.[140] In his "Grammar of Geology," Eaton described an "alphabet" of nine minerals and their characteristics, with lengthy descriptions of all the strata.[141] To interpret the strata he

[138] Eaton, 1820, 280.
[139] Eaton, 1820, vi-vii.
[140] "For the convenience of learners, I shall adopt the following theory." Eaton, 1820, 13.
[141] Eaton, 1820, 17-51.

advised his readers: "With respect to the theoretical part, as far as I have given in to any theory, it is to that of Werner, with the improvements of Cuvier and Bakewell.*"[142] Cuvier, Bakewell, and Deluc "contain every thing to gratify the most brilliant fancy, or the most rational curiosity."[143]

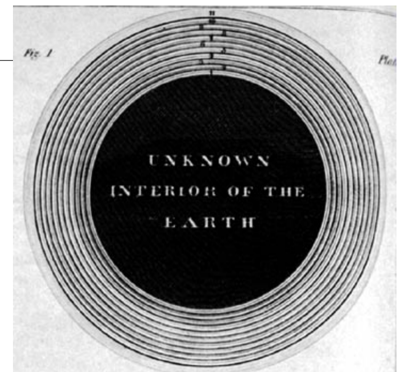


FIGURE 221. Amos Eaton, *Index,* 1820, *Plate 1,* figure 1 (Day 2). LH and HSCI.[144]

Description. *Figure 1* of *Plate 1* depicts a global section on the second day of the creation, with the "Unknown Interior of the Earth" shown as a dark region surrounded by 11 numbered, concentric formations, not including Secondary and more recent strata. Four outer strata are transition rocks, formed after creation of marine animals.

TABLE 68. Plate 1 key

No.	Formation	Comment
1	Granite	1st Primitive stratum
2	Gneiss	
3	Hornblende rock	
4	Mica slate	
5	Talcose rock	
6	Granular limestone	last Primitive stratum
7	Argillite	1st Transition stratum?
8	Metalliferous limestone	1st Transition stratum
9	Graywacke	Transition stratum
10	Red standstone	last Transition stratum
11	Muddy waters surrounding earth	Will give rise to Secondary & alluvial strata

Eaton explained his views by referring to the "sacred system of geology, given by Moses" which established the beginning of the Earth from a chaotic mass. The watery chaos of the

[142]Eaton, 1820, vi. ("*It is much to be regretted, that Bakewell is not yet reprinted in America.")

[143]Eaton, 1820, 278.

[144]Amos Eaton, *An Index to the Geology of the Northern States, with Transverse Sections, extending from Susquehanna River to the Atlantic, crossing Catskill Mountains; to which is prefixed a Geological Grammar,* 2d ed. (Troy, N.Y.: Published by Wm. S. Parker, sold by him; Albany: by Websters and Skinners [and six others], 1820). Hereafter, "Eaton, 1820."

second day is corroborated by evidence that the interior of the Earth is twice as heavy as the crust, and must be "several concentric layers of metals, of different specific gravities, arranged like the coats of an onion" (Figure 221).[145] The less heavy materials settled in succession until the granite was deposited:

> Such was the density of the chaotic solution, that it required several thousands of years for the completion of all the strata. This account is not contradicted by Moses' history of the creation. For the six days cannot be supposed to have been equal to six apparent diurnal revolutions of the sun, as no such regulation was then made. During several of the first days the greater light was not appointed to rule the day, nor the lesser light to rule the night. Consequently time could not have been measured as at this day. But with the Lord a thousand years are as one day, and one day as a thousand years.[146]

For Eaton, the six days were too short unless the processes were "hastened." Apparently in response to personal criticism, in the 1820 edition Eaton backed off this day-age interpretation in favor of hastening.[147]

In the Transition period, still the second day (Figure 221), substances lighter than granite were deposited, together with entangled parts of the heavier substances. The water became more dilute, and zoophytes "endowed with capacities suited to this half chaotic state of the earth" were created while the transition rocks were deposited.[148] Several species of fish were created at the close of the transition.

[145]Eaton, 1818, 44.
[146]Eaton, 1818, 44.
[147]Eaton, 1820, 276.
[148]Eaton, 1818, 45.

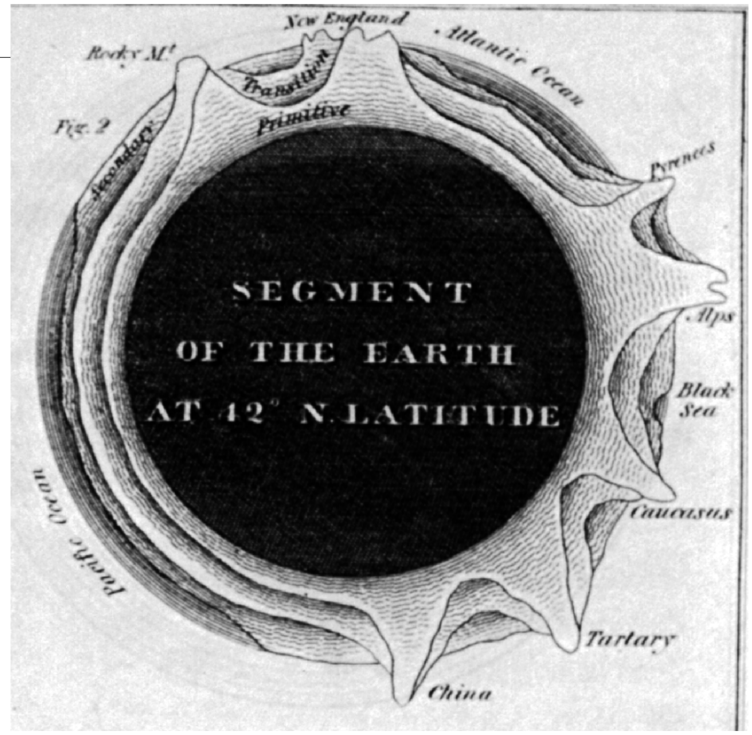


FIGURE 222. Amos Eaton, *Index*, 1820, *Plate 1*, figure 2

Description. This section depicts a "Segment of the Earth at 42° N. Latitude" where primitive strata have been elevated to form mountain ranges, with transition and secondary formations resting upon them.

The Secondary strata represent the products of the third day of creation (Figure 222). With more dilute water, the secondary deposits "went on with considerable rapidity."[149] More complex organisms were entombed. The internal heat of the Earth converted subterranean water, immediately beneath the granite, into steam, which began to elevate the granite resulting in islands and continents.[150] Eventually the steam burst through the weakest parts of the strata.

Before the elevation of the granite on the third day, alluvial deposits had already formed (in Eaton's terminology they are not solely artifacts of the deluge). These deposits prepared the elevated land for the plants and animals to be created there. "'Let the waters be gathered into one place and let the dry land appear.' Then it was, that by the expansion of vapor the vast steam engine of nature first began to shoot forth the granitic rocks above the muddy waters, with the ponderous strata of other rocks on their backs."[151] Eaton explained that

[149]Eaton, 1818, 45.

[150]Eaton, 1818, 46: "As strata can be separated from each other easier than they can be broken through, the steam probably extended laterally around the earth, separating the granite from the next stratum below it."

[151]Eaton, 1818, 49-50.

> the rents made by the grand explosion, which first upturned and disfigured the rocky crust of the globe, were in a north and south direction. That those, crossing the 42nd degree of north latitude, were principally made at the Pyrenees and Alps in Europe, Caucasus, Tartary and China in Asia, Rocky Mountains and New-England in America. They are represented in *Fig. 2*."[152]

In Figure 222 the names of three classes are shown for North America, at the top of the world. Secondary rocks, which contain petrifactions of terrestrial as well as marine animals, are more recent than *figure 1* and are here represented for the first time. By the end of the third day, the Earth no longer fits an onion-skin model. Many local superincumbent strata and alluvial rocks have not yet formed.

Foldout *Plate 1* (Figure 223) has three figures: the two global sections already discussed, and a regional transverse section with the strata numbered from 1 (granite) to 16 (greenstone trap), demonstrating "Strata interrupted undulated and in some places wanting." An explanation is offered on p. 280, identifying the strata in this transverse but still idealized section "to represent a secondary country, where both transition and secondary rocks appear. By attending to the numbers of the interrupted fields and patches of different strata, a pretty correct view of the secondary country to the west may be formed."[153] This ideal section completes a smooth, seamless transition between the two global sections and the regional transverse sections obtained by Eaton's fieldwork. Eaton wrote that the regional sections of *Plate 2* (Figure 220 on page 697) "represent similar strata with those set down for *Fig. 3, Plate 1*."[154]

[152]Eaton, 1820, 16.
[153]Eaton, 1820, 280.
[154]Eaton, 1820, 280.

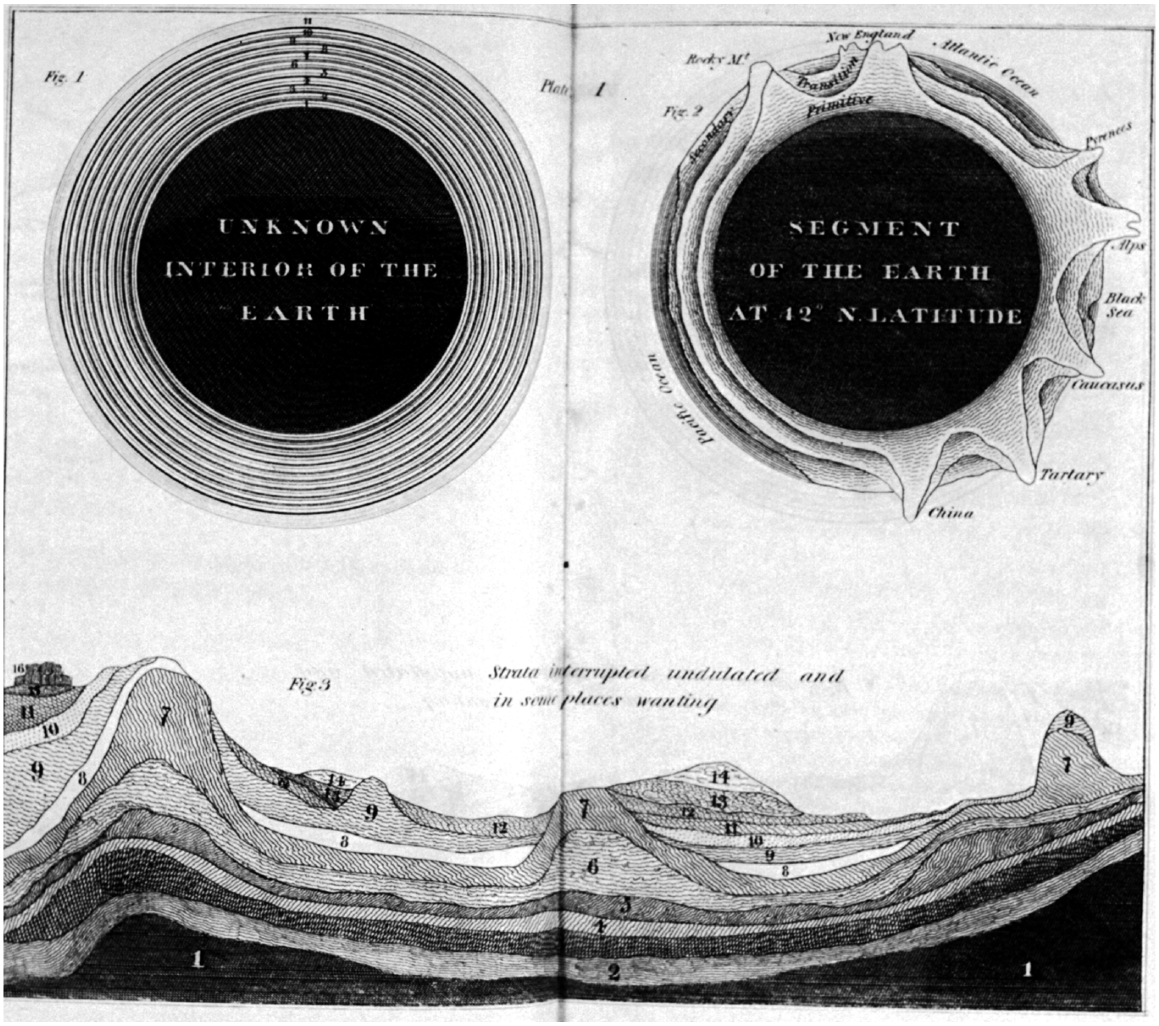
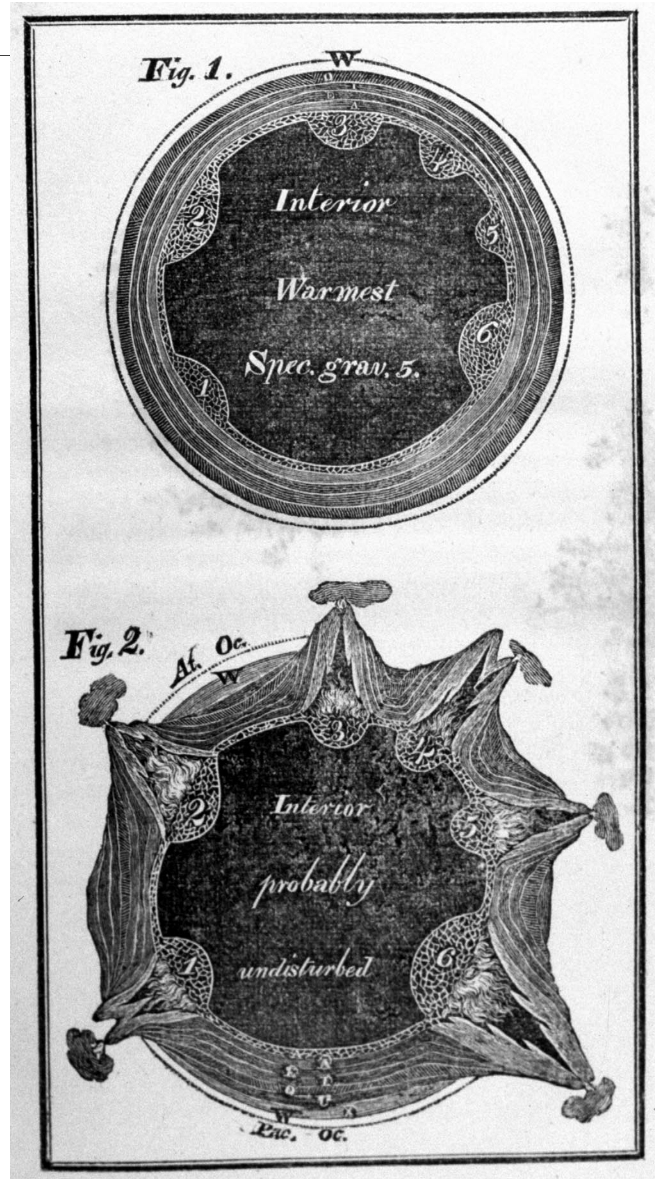


FIGURE 223. Eaton, *Index*, 1820, *Plate 1*, figures 1, 2 and 3.

FIGURE 224. Amos Eaton, *Geological Text-Book* (1830), *Figures 1* and *2*. HSCI.

Caption. "Exhibition of Two Transverse Segments. The earth is here supposed to be cut into two parts, at the 42° of north latitude. The observer is supposed to stand south of the center of the segments—all the earth, south of him, being removed."



To conclude, Eaton's illustrations synthesize Wernerian geognosy and non-Wernerian causal mechanisms of igneous uplift in a temporal framework provided by hexameral idiom and based upon first-hand fieldwork. In one sense his Theory was not a cosmogony, for Eaton did not discuss the origin of the Earth or the first day. Although he accepted igneous elevation (that "vast steam engine of nature") and the volcanic origin of basalt,[155] he remained unabashedly Wernerian in his loyalties and regarded Werner's system as in some ways a more helpful guide for American geology than the geology of Bakewell or Cuvier.[156] Although details of the subsequent modification of his views are not relevant here, by 1830 Eaton had abandoned neither his profession of Wernerianism nor his hexameral approach. *Figures 1 and 2* (also reprinted without change in 1832), represented "an improvement upon those pub-

[155]However, Eaton still regarded granite as an aqueous precipitate from the waters of the second day.

lished in my *Geological Index*, in 1820, and afterwards copied into Woodbridge's Geography."[157]

§ 7-iii. Wernerian Historical Geology redivivus

Eaton's practice of geognostic fieldwork in the context of a hexameral Theory of the Earth provides an appropriate opportunity to reconsider the question addressed in Chapter 1 about the historical character of Wernerian geognosy. Examining different actors in turn from Hooke through the eighteenth century, Oldroyd finds their historical sensibilities wanting. When he comes to Humboldt and the Wernerians, Oldroyd writes that, for them, "The regular succession of strata seems to have represented an expression of the law-like characteristics of the Earth's structure and history." Oldroyd implies that the law-like ordering of temporal entities discerned by geognostical practices is compatible only with genetic rather than truly historical views.[158] Yet the pre-eminent Werner scholar Alexander Ospovat refers to Werner as an historical geologist. Historians of geology currently line up on both sides of this argument; Martin Guntau and Rachel Laudan agree with Ospovat that Wernerian geognosy was authentically historical, and Albert Carozzi sides with Oldroyd in arguing against Laudan. Here we resume the discussion of Wernerian geognosy begun in Chapter 1, citing Eaton's hexameral Theory of the Earth as a test case.

[156]Two examples are Eaton, 1818, 24: "Bakewell believes the sienite to be of volcanic origin. Perhaps he would not, should he visit our sienite rocks." And Eaton, 1818, 31: "Bakewell removed this stratum [red sandstone] from the secondary class, where Werner placed it, to the transition. He says, this stratum terminates the series of transition rocks containing metallic veins and the more ancient relics. Had Bakewell ever visited Catskill mountain, he would undoubtedly have left the red sandstone where Werner placed it. For here the true old red sandstone of Werner contains the organized remains of at least one well-known phenogamous woody plant. As this is an important fact, which may be questioned by geologists, I will be very particular in my directions."

[157]Eaton, 1830, 18.

[158]Oldroyd cautions that geognosy involved merely the working out of the spatial relations of mineralogical units—a geometrical ordering of rock suites—not the elucidation of the globe's history. Given the consensus among early nineteenth-century geologists that Werner was a Theorist of the Earth, it seems incongruous that Oldroyd and Rudwick would emphasize that geognosy was too factual, preoccupied with structural relations at the expense of temporal inferences.

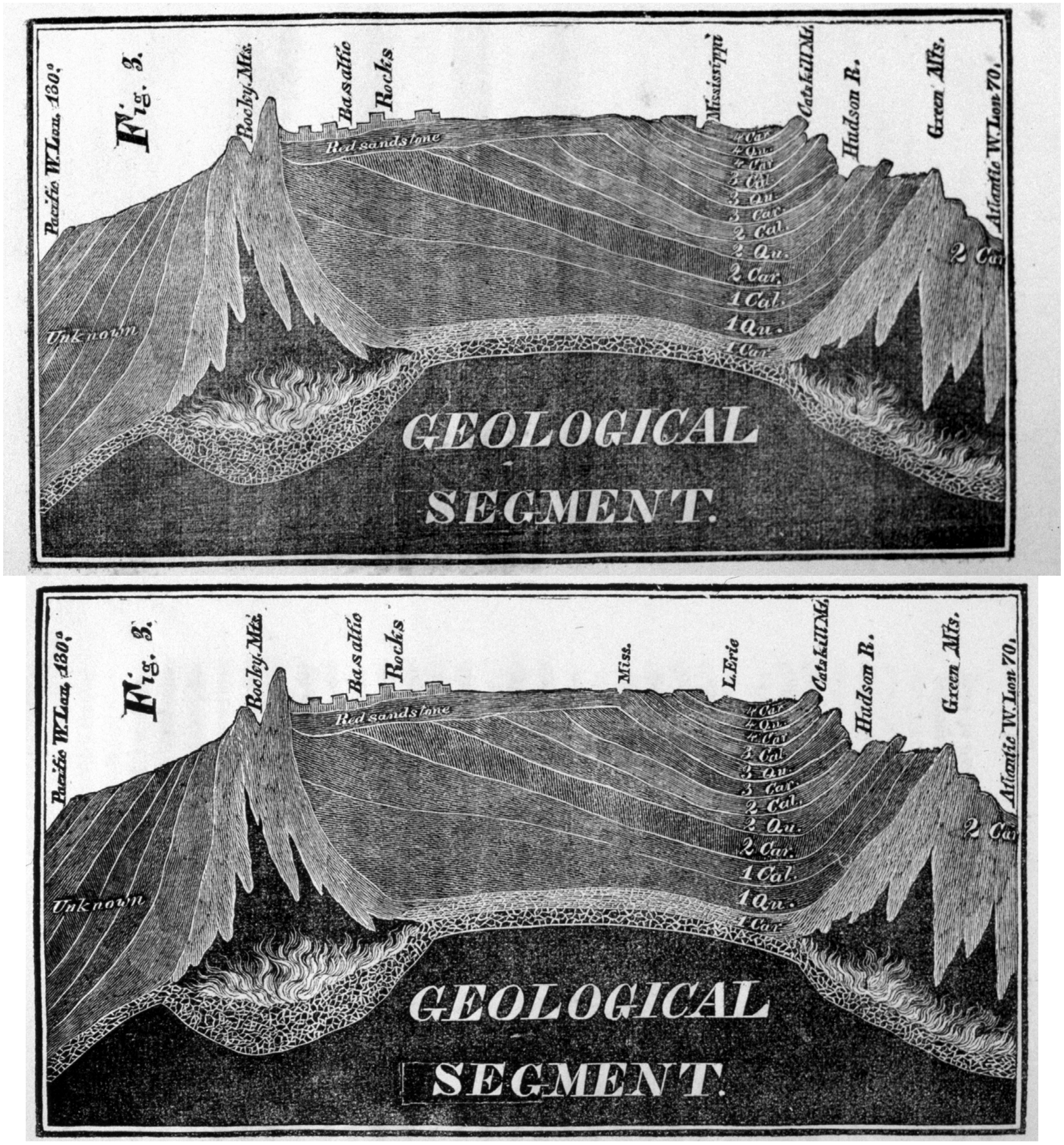


FIGURE 225. Amos Eaton, 1830 (top) and 1832 (below); *Figure 3*. HSCI.

Caption. "Exhibition of a Transverse Segment. The continent of North America is here supposed to be cut into two parts between the 42° and 43° north latitude. The observer is supposed to stand south of the middle of the segment—that part of the continent which is south of him being removed."

Description. Note identification of the Mississippi River (1830) and Lake Erie (1832).

1. Phenomenological Laws of Observations in the Field

Oldroyd is certainly correct to describe the knowledge sought by geognosts as lawlike. Few would suggest that the Wernerian system was chaotic, for it rested upon a deep consistency or pattern of observed regularities in the succession of formations. In a passage from his geognostical essays already quoted, Humboldt insisted on the search for regular, law-like patterns in order to distinguish the endeavor from theoretical speculations based on causal hypotheses: "These subjects are not mere theoretical speculations; far from being useless, they lead us to the knowledge of the laws of nature."[159] However, the lawfulness of geognostic observations did not diminish their character as historical inferences. Rather, Humboldt pointed to this quality of geognosy in defense of its non-causal status. For Humboldt, Wernerian geognosy involved the reconstruction of a series of past events based on presently-existing artifacts assumed to have formed at specific, particular times:

> Le mot *formation* désigne, en géognosie, ou la manière dont une roche a été produite, ou un assemblage (système) de masses minérales qui sont tellement liées entre elles; qu'on les suppose formées à la même époque, et qu'elles offrent, dans les lieux de la terre les plus éloignés, les mêmes rapports généraux de gisement et de composition. C'est ainsi que l'on attribue la *formation* de l'obsidienne et du basalte aux feux souterrains; c'est ainsi que l'on dit que la *formation* du thonschiefer de transition renferme de la pierre lydienne, de la chiastolithe, de l'ampélite, et des couches alternantes de calcaire noir et de porphyre. La premiére acception du mot est plus conforme au génie de la langue; mais elle a rapport à l'origine des choses, à une science incertaine qui se fonde sur des hypothèses géogoniques. La seconde acception, aujourd'hui généralement reçue par les minéralogistes françois, a été empruntée à la célèbre École de Werner: elle indique ce qui est, non ce que l'on suppose avoir été.[160]

This quotation is outlined in Table 69, which makes clear Humboldt's contrast between the genetic, causal explanations of a *geogony* and the historical, phenomenalist explanations of *geognosy.* Humboldt characterized geognosy as a science of contingent events established by

[159]Alexandre von Humboldt, *A Geognostical Essay on the Superposition of Rocks, in Both Hemispheres* (London: Printed for Longman, Hurst, Rees, Orme, Brown, and Green, 1823), vi.

[160]Alexandre von Humboldt, *Essai Géognostique sur le Gisement des Roches dans Les Deux Hémisphères* (Paris: Chez F. G. Levrault, 1823), 1–2. This work was published simultaneously in French and English; the English translation of this same quotation appears where discussion of it was introduced above, page 119.

fieldwork rather than a set of causal hypotheses tested in the laboratory. Before Cuvier's Theory of the Earth, in a mineralogical textbook the quintessential Wernerian Robert Jameson similarly advised his students on the centrality of evidence from the field.[161] Eaton's emphasis on fieldwork as the basis of his views continued this geognostic technical tradition.

TABLE 69. Causal and Historical Meanings of "Formation" (Humboldt)

	A. Causal	B. Historical
Defined by... (A) means of production, or by (B) structural relations expected to display a widespread consistency on the basis of their assumed contemporaneity?	"the manner in which a rock has been produced..."	"an assembly of mineral masses... intimately connected..." "formed at the same epoch" "present, in the most distant parts of the earth, the same general relations, both of composition, and of situation with respect to each other"
Examples	"Thus the formation of obsidian and basalt is attributed to subterraneous fires"	"...the formation of transition clay-slate contains Lydian stone, chiastolite, ampelite, and alternating beds of black limestone, and of porphyry."
Usage	"most conformable to the genius of the French language"	"now generally received by the French mineralogists... borrowed from the celebrated school of Werner"
(A) Uncertain causal hypotheses about unobservable means of production in the past, or (B) Geognostical observations of present-day artifacts of inferred historical events	"relates to the origin of things, and to an uncertain science founded on geogonic hypotheses"	"indicates, not what is supposed to have been, but what now exists"

161 "The descriptions and inferences we are about to detail, can only be fully understood, and the gratification derived from them completely enjoyed, by an intimate acquaintance with Nature herself, not in cabinets alone, but in mines and among mountains.... Our researches on the surface of the earth... often lead us among the grandest and most sublime works of nature;.... In the midst of such scenes, he [the geognost] feels his mind invigorated; the magnitude of the appearances before him extinguishes all the little and contracted notions he may have formed in the closet; and he learns, that it is only by visiting and studying these stupendous works, that he can form an adequate conception of the great relations of the crust of the globe, and of its mode of formation." Robert Jameson, *Elements of Geognosy,* vol. 3 of *System of Mineralogy: Comprehending Oryctognosie, Geognosie, Mineralogical Chemistry, Mineralogical Geography, and Oeconomical Mineralogy,* 3 vols. (Edinburgh, 1808); facsimile reprint Robert Jameson, *The Wernerian Theory of the Neptunian Origin of Rocks,* ed. Jessie M. Sweet (New York: Hafner Press, 1976), 43.

2. Wernerian Geognosy not Primarily Causal

However, there is another sense in which geognostical knowledge was not lawlike: the Wernerian approach was not reducible to the natural laws of chemical and physical causation. No mineralogical system enabled Werner to predict the succession of formations from chemical or physical causes. The composition of the primeval ocean, the specific reactions which occurred, and the sequence of the precipitations that resulted were all unknown—or at best reconstructed on the basis of the observed regularities in the field and in the mine. The gradually-diminishing primeval ocean was a supposition, not a causal demonstration, in the *Kurze Klassifikation*; this is particularly evident in the postulated resurgence of the primeval ocean required to explain repeated formations of the same mineralogical character. The action of natural causes might produce contingent regularities (lawlike patterns of formations) that were unpredictable though not unintelligible, and a series of unique events were inferred from these regularities. Thus the event represented by a given formation was not deduced from prior causes, but contingently known.[162] For example, Eaton resolved the problem of the classification of the Red Sandstone by field evidence, not through deductions from chemical or physical laws.

3. Wernerian Formations not Primarily Mineralogical Entities

The ease with which geognosts such as Eaton assimilated Wernerian classifications of rocks into hexameral idiom suggests that the Wernerian formations were temporal as well as mineralogical entities, perhaps in contrast to some English structural geologists such as Smith or Conybeare. The conceptual priority of age over mineralogy for geognosts is also indicated, for example, in Werner's distinction of two limestone *Gebirgen*: a primitive kind, finely granulated, quartz-containing, and nonfossiliferous; and a floetz kind, of gray color, containing

[162]Consider Humboldt's phenomenalist epistemic aim: "As we are ignorant of the primary causes of phenomena, natural philosophy, of which geognosy will one day form one of the most interesting parts, ought to stop at the knowledge of laws...." Humboldt, *Geognostical Essay*, 74–75.

marine fossils, and usually in alternating beds with marl and stinkstone.[163] *Gebirgen* with similar modes of formation and therefore mineral composition, but different age of formation and therefore relative position, were distinguished with different designations. For example, three different common sandstones were formed at different times in the Flötz period.[164] Mineralogical characteristics, while significant, played a supporting role and were chiefly important as providing evidence for the period or mode of formation (along with the principle of superposition). With Brongniart, Cuvier, and students of Werner's such as Ernst von Schlotheim (1765-1832), fossils became the major indicators of period of formation.[165]

4. Wernerian Formations as Historical Entities

That contingent temporal events comprised the fabric of the Wernerian system was recognized by contemporaries. For example, this was the basis of Hutton's objection to the views of mineralogists on the same meta-theoretical level as his rejection of Buffon and Deluc:

> But, allowing those suppositions [about the dissolving power of water] to be true, there is *nothing in them like a theory of the earth*,—a theory that should bring the operations of the world into the regularity of ends and means, and, by generalizing these regular events, show us the operation of perfect intelligence forming a design; they are only an attempt to shew how certain things, which we see, have happened without any perceivable design, or without any farther design than this particular effect which we perceive."[166]

As Rachel Laudan has demonstrated, for Werner each particular formation was regarded as unique because it was laid down at a specific time. A formation represented an event—a lawful event, to be sure, but not a law. Because a formation in one place represented an event of more than regional extent, there was a basis in the very temporality of the definition for

[163]Werner, *Kurze Klassifikation,* Sections 16 and 20, trans. Ospovat, pp. 64, 70. By 1802 Werner similarly distinguished two formations of chert, one primitive (occurring in conformity with clay slate) and another transitional between the primitive and floetz periods (Ospovat, p. 113-114).

[164]Ospovat, p. 132, n. 55; p. 23; cf. Werner, *Kurze Klassifikation*, Section 21, p. 70.

[165]Cf. Laudan, *From Mineralogy to Geology,* 142ff.

[166]The principles explored by the theorist of the Earth should be those which "procure it [the Earth] a perfection which it is our business to explore." Hutton, *Theory of the Earth* (1795), 275; italics added.

extrapolating the lawlike patterns of succession to distant regions. Alexander Ospovat has shown that Werner's views did not uncritically derive from an unexamined extrapolation of his regional fieldwork to the rest of the world, but derived from his earlier conclusion, on the basis of textual and other studies which predated that fieldwork, that the Earth was homogenous and its formations were correlative.

According to Rachel Laudan, in the generation following Werner, "'formations' replaced the old commonsense mineral classes as the key concept in reconstructing the past." In consequence, historical geology (which classified rocks according to age) diverged from causal mineralogy. This differentiation was "latent in Werner's work but never systematically explored" by him.[167] Werner derived his "theory of the successive deposition of rocks from aqueous solution, and... the definition of rocks in terms of age as well as mineralogy" from the Becher-Stahl tradition of chemical cosmogony.[168] Laudan argues that this temporal dimension was inherent in the geognostical program:

> But during the course of his career, Werner transformed the Becher-Stahl tradition from which he had taken so much. He made the time of formation of rocks, not their mineralogy, their most important character. Well aware that he was flouting the precepts of taxonomy, he named bodies of rock formed in the same period 'formations,' and he made these historical entities - formations - more important than chemical ones. He concentrated on the earths at the expense of the metals, and on rocks at the expense of veins.... Werner's adoption of the term geognosy signaled this change of emphasis.[169]

Werner's formations were "unique, historical entities defined by their age and their mode of formation."[170]

[167]Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650-1830* (Chicago: University of Chicago Press, 1987), p. 138. Cf. p. 141: "Werner had explained the several characters of rocks and formations in terms of a single causal agency - the shifting chemical composition of the ocean in which they had been laid down. Unlike later stratigraphers, he postulated a causal connection between the order of deposition of the formations and the mineralogy of formations. In Werner's cosmogony, causal geology and historical geology still referred to many of the same entities and seemed to be complementary. But Werner's nineteenth century successors had no explanation to offer for the relationship between the order of formations and their mineralogy."

[168]Laudan, *From Mineralogy to Geology*, 87.

[169]Laudan, *From Mineralogy to Geology*, 88.

It should make no difference to the question of the development of historical sensibilities in geognosy whether modern geologists define "formations" temporally, lithologically, or spatially. Nevertheless, Albert Carozzi contends that the modern ahistorical definition of "formation" invalidates Laudan's interpretation of Werner's significance for "historical geology."[171] Yet it should be clear that in the *Kurze Klassifikation* Werner considered the period of formation of rock masses as more important than their mineralogy, making rock formations unique historical entities rather than natural kinds, the subject of a new science of geognosy (as Laudan contends). For example, Werner preferred the term "Primitive" rather than Primary precisely because of its temporal implication.[172] Werner wrote (in a passage cited in part by both Laudan and Carozzi):

> On the contrary, in the design of this classification and description I have focused my sole attention on the various large rock masses, as far as these can be observed, of which nature has built our solid earth; on the search for their essential differences, based on their mode and time of formation; and on the classification and characterization of these differences according to the nature of these rock masses. For in what way can the examination of aggregated rocks help us?[173]

Laudan comments that

> Werner insisted that the 'essential differences' between rocks of various kinds were 'mode and time of formation' [citing the above passage]. In line with this defini-

[170]Laudan, *From Mineralogy to Geology*, 95.

[171]Although his argument relies on a Whiggish use of modern definitions, Carozzi distinguishes three historical senses of "formation": "Moreover, what Werner called "formation," intrinsically contains a time factor and is therefore quite different from the modern definition of a formation, namely a lithologically defined unit devoid of time concept. Therefore, Werner's "formation" could not be the central part of "historical geology" because the latter is based on the time concept, that is the succession of time rock units such as Devonian or Jurassic defined by index fossils." Albert V. Carozzi, review of Laudan, *Earth Sciences History* 1988 (Dec.): 159. (Emphasis his.) The first sense of formation is Werner's, which incorporated a time factor; the second is the modern usage which is dissociated from time factors and based on lithological factors instead; and the third (perhaps meant to be understood as modern) is that of nineteenth century historical geologists which incorporated a time factor defined by index fossils. Carozzi asserts that the "index fossil" sense is unrelated to Werner's, though both incorporated time considerations. Carozzi may be suggesting (in opposition to Laudan) that the use of index fossils was added by nineteenth century historical geologists to a non-Wernerian framework of structural geology, in order to determine the temporal succession of lithologically-defined formations. However, Laudan demonstrates that temporal interpretations of geological structural relations derived from the Wernerian adaptive radiation more than from the non-temporal geology of Strachey and others.

[172]See page 123.

[173]Trans. in Ospovat, p. 19.

> tion, he coined the term *Gebirgsformation*, or 'rock formation,' to describe the major rocks making up the earth's surface.... [This term] signals a very important shift in the development of geology.[174]

Carozzi accuses Laudan here of truncating Werner's quoted passage in an unscholarly manner so it is important to consider Laudan's comments at length:

> Werner's phrasing of his definition is crucial. It indicates that he believed that the geologist should group together rocks of the same age and mode of formation, even if their other characteristics, such as mineral composition, varied. Thus, Werner rejected the two standard ways of distinguishing rocks; he followed neither the miners' use of method of working, extent, and location, nor the mineralogists' use of constituent minerals. He was not the very first to do this, but was anticipated by Füchsel, Lehmann, and others. Nonetheless Werner was the one who made the formation the central concept of historical geology.[175]

According to Laudan, then, Werner brought rock formations to central focus in historical geology because he gave their age and mode of formation priority in classification over their mineral composition. According to her analysis, this trend represents a separation of historical geology from causal mineralogy, although in Werner's own work historical geology and mineralogy remained causally connected.

To summarize, some of the temporal aspects of Wernerian geognosy include:

- A preference for temporal nomenclature (e.g., Primitive class). For Theorists such as Eaton, hexameral idiom reinforced this temporal dimension.
- The contingent diminishing of the primeval ocean, interrupted by occasional unpredicted episodes of rising sea level.
- Giving priority in distinguishing formations to characteristics which allowed inferences of the epoch of origin (superposition, location, and sometimes fossils), over mineralogical characteristics.
- Defining universal formations as temporal to provide the logical basis for extrapolating regional results to distant areas around the globe.

Geognosy was neither purely structural nor completely causal, but contingently historical. Werner asserted that he had undertaken the *Kurze Klassifikation* "in order, as far as this is pos-

[174] Laudan, p. 94.
[175] Laudan, p. 94.

sible, to form an opinion about and to tabulate these formations in their entirety...." Therefore, he wrote:

> I had to be guided in the classificatory presentation or tabulation of these masses by the discoverable time sequence of the particular formations if I wanted to remain true to my plan to sketch through this classification a foundation for a complete canvass of the universal formation of these masses.[176]

These comments support Laudan's interpretation, in spite of Carozzi's objection, that Werner gave age and mode of formation priority over strictly mineralogical considerations in the definition and classification of various *Gebirgen*. Even if Werner himself did not do so, Eaton's work was carried out under the mantle of Werner as a mutually-reinforcing mix of hexameral idiom, Theory of the Earth, geognosy and historical geology.

[176]Werner, unpublished manuscript, trans. Ospovat, p. 20 (emphasis mine).

§ 8. Visual Texts

Were Theories of the Earth a characteristically visual tradition? No, unlike technical traditions such as nineteenth-century stratigraphy in which technical visual depictions became obligatory or even self-contained.[177] Illustrations of various kinds were common in Theories of the Earth, as we have seen, but visual elements were neither considered essential nor uniformly employed. Ornamental representations, the most dispensable kind, might provoke contemplation in the manner of emblems or icons, such as Burnet's deluge or Buffon's cometary collision with the Sun. Yet as has already been noted, John Woodward's Theory was not illustrated in the first English edition, nor did John Keill resort to visual means to refute the visual embodiments of Burnet's and Whiston's Theories.[178] While the latter Theories would have been unimaginable without images, the verbal components provided a sufficiently substantive target for the critic's attention—or, as in the case of Whiston, the diagrams were creatively appropriated from their original context and deployed for the support of rival Theories.

Evidential illustrations are found in many Theories of the Earth, though they are not the most prominent and are not focus of this study. More abstract evidential illustrations include local sections such as those drawn by Whitehurst or described by Rudwick as the visual language of geology. More representational, naturalistic depictions focus attention on particular pieces of evidence or pertinent, relevant features of objects, such as Galileo's lunar cavity; Steno's shark's head and other anatomical illustrations; Saussure's alpine vistas; Hutton's granitic intrusions and the Jedburgh unconformity; Hooke's depictions of extraneous fossils; and Hamilton's depictions of Italian volcanos. More naturalistic representations engage the imag-

[177]Rudwick has analyzed the transformation of geology into a visual science in the decades before 1830: "During the period in which 'geology' emerged as a self-conscious new discipline with clearly defined intellectual goals and well established institutional forms, there was thus a comparable emergence of what I shall call a *visual language* for the science..."; "Visual Language," 150.

[178]While Erasmus Warren did include diagrams to critique Burnet, they were not deployed to illustrate or advance his own alternative Theory of the Earth. Moreover, they were as superficial as his use of geometry and physics, and did not add anything substantial to his argument.

ination, often by impressing upon it the singular, striking effects of a particular ensemble of circumstances.[179] Naturalistic representations were often closely associated with natural history, and with hexameral idiom and practices of biblical illustration. The landscape scenes of Scheuchzer (see Appendix) and Parkinson represent confluences of these traditions.[180]

However, in contrast to evidential and naturalistic representations, didactic illustrations—global sections and global views—are most prominent in Theories of the Earth. Geogonic global sections didactically represented the formation of the globe through natural processes, whether physical, chymical or mechanical. They could convey directionalist or cyclical sensibilities. In contrast, many global views depicted events, specific conditions, or perhaps a contingent history. Non-geogonic global sections were offered as ideal suppositions to explain known surface features, based upon travel observations, or significant local or regional phenomena. Both sections and views were associated with cosmology and hypotheses regarding the formation of other worlds. Global illustrations were frequently accompanied by regional illustrations, perhaps transverse sections of particular localities. Their didactic role is consistent with the extra burden of a writer in a textual tradition to explain just what one means in an accessible way. Didactic illustrations not only widely disseminate ideas, but by clarifying ideas and sharpening thoughts they effectively compel agreement. In the midst of an extensive analysis of the geographical conventions that shaped Galileo's lunar illustrations, Montgomery remarks: "These images are far more than 'visual aids'; they are attempted fixatives of sensibility, perception, and belief."[181] Usually neither overly abstract nor overly naturalistic, nontechnical didactic images create a discourse and sustain a *public* debate.

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[179]This aspect of naturalistic representations is brilliantly analyzed in Charlotte Klonk, *Science and the Perception of Nature: British Landscape Art in the Eighteenth and Early Nineteenth Centuries* (New Haven: Yale University Press, 1996).

[180]See Rudwick, *Scenes from Deep Time*, for a careful analysis of Scheuchzer, Parkinson, and nineteenth-century representations of the Earth's past in a naturalistic way; cf. John C. Thackray, "James Parkinson's Organic Remains of a Former World (1804–11)," *Journal of the Society for the Bibliography of Natural History*, 1976, 7: 451–466.

Often global sections were drawn to illustrate theoretical questions involving the inaccessible interior of the Earth. Questions about the Earth's unseen interior seem to have more to do with the problems of late nineteenth-century geophysics than with early nineteenth-century historical geology, but they could play a critical role in evaluating forces which Theorists such as Kircher, Woodward, and Erasmus Darwin called upon to explain surface features such as volcanos, mountains, or strata. Because of the relationship of the postulated interior structures to the specified surface features the sections were frequently drawn with a greatly exaggerated vertical scale, *i.e.*, depicting with great enlargement the heights of mountains and the depths of the seas, the thickness of the strata, or even sketching in a sign of human habitation such as a ship or a house. The exaggerated vertical scale reflects the theoretical interest of the surface phenomena, such as the changing level of the oceans, the elevation of mountains, and the order of the strata.[182] Not every causal agency postulated to account for these phenomena carried theoretical implications for the Earth's core, however, and the use of global sections is in no way a *sine qua non* of Theories of the Earth. Many Theorists, like Whiston, could appropriate a smooth drawing to represent a rough terrestrial surface, or like Steno, find global sections to be dispensable.

In 1839 Henry Thomas De la Beche published a global section drawn to the same vertical and horizontal scales (or radial and angular scales).[183] That is, he illustrated the height of

[181] Montgomery, 125. Montgomery's analysis is worth quoting at length: "The distortions and exaggerations he [Galileo] visited upon the lunar face were more extensive than already mentioned. Aside from the terminator, to which he gave an excessively scalloped appearance, or the apocryphal 'largest cavity,' he also provided an overly smooth look to lighter areas within the western maria. The prominent 'explosive' craters Tycho, Copernicus, and Kepler are missing entirely despite the fact that one or more of them would certainly have been plainly visible, particularly given the number of other craters that Galileo drew. Galileo chose to edit the lunar surface so that it would look more Earth-like than it was, removing the most alien features and contouring others in accord with certain conventions of geographic representation for maps.... I am suggesting that Galileo drew the Moon according to certain conventions of pictorial rhetoric in late Renaissance mapmaking that governed the delineation of coastlines, islands, peninsulas, headlands, basins, and so forth. These conventions were guides that helped him sort through the mass of complex visual impressions."

[182] Theorists certainly knew that mountains were not actually as high as their sections indicated. For example, Kircher estimated the height of Etna at thirty miles which, while exaggerated by comparison to a modern estimate, is nothing compared to the diameter of the Earth (which he knew).

[183] Henry Thomas De la Beche, *Sections and Views, illustrative of geological phenomena* (London, 1830).

the mountains and the depth of the oceans to the same scale as the diameter of the Earth. This rhetorical exercise was the antithesis of Burnet's rough globe, emphasizing the relative smoothness of the terrestrial surface.[184] Like De la Beche, Burnet also knew that mountains were not so high in comparison with the diameter of the Earth, but De la Beche's global section indicates a shift in postulated causal agencies. For De la Beche, the heights of the mountains and the depths of the ocean were not so great as to require unimaginable global mechanisms to explain them.[185]

TABLE 70. Relative Sizes of the Earth and its Crust

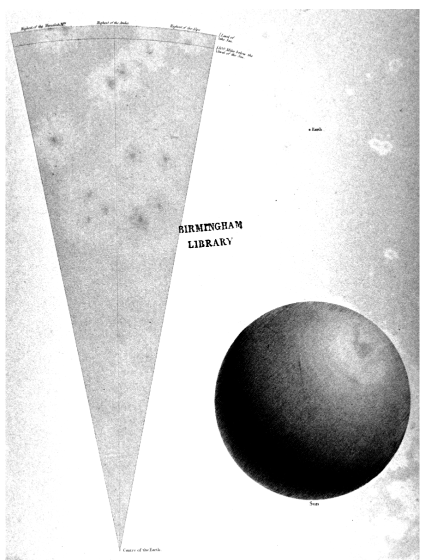
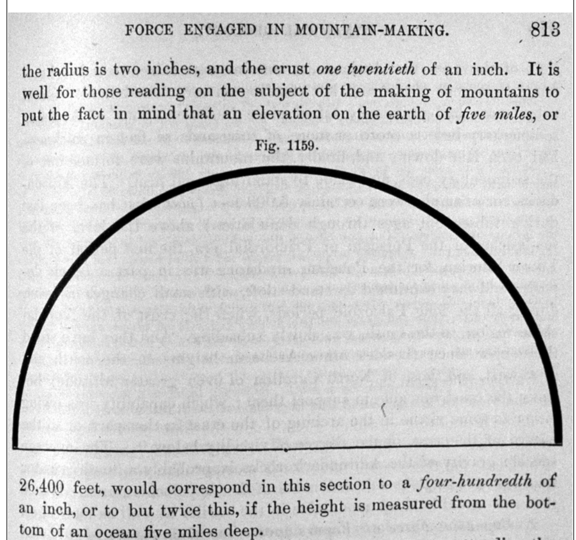


FIGURE 226. De la Beche, global section of the Earth alongside global views of the Earth and Sun (drawn to the same scale).



FORCE ENGAGED IN MOUNTAIN-MAKING. 813

the radius is two inches, and the crust *one twentieth* of an inch. It is well for those reading on the subject of the making of mountains to put the fact in mind that an elevation on the earth of *five miles*, or

Fig. 1159.

26,400 feet, would correspond in this section to a *four-hundredth* of an inch, or to but twice this, if the height is measured from the bottom of an ocean five miles deep.

FIGURE 227. Dana, *Manual of Geology.*

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[184]De la Beche urged geologists to produce "sections more conformable to nature." Disproportionate scales, in particular, were regretted, and several plates (e.g., *Plate I*) are directed toward illustrating the value of constant proportions. *Plate II*: "This Plate is intended to illustrate the value of proportion in geological sections generally. From a want of attention to this subject, the greater part of such sections are more mischievous than useful, and tend to mislead rather than to instruct the geologist." de la Beche, *Sections and Views,* 3. *Figure 1* gives the true proportions of the heights of a mountain range, from Jura to Mont Blanc. *Figure 2* is a section of the English Channel to the same scale, drawn as a single black line! "If true sections were made of most coasts, and continued some distance both on the side of the dry land and on that of the sea, geologists perhaps would entertain less exaggerated ideas respecting the depths of the ocean than they now do." de la Beche, *Sections and Views,* 3. One may note the limit to de la Beche's visual rhetoric in that while de la Beche depicted the Earth and Sun with their diameters to the same scale, he did not use the same scale for their distances!

It is clear from this study that visual illustrations teach and instruct a reader, and do not merely adorn a text. The global sections of Descartes and Burnet, Steno's diagrams of strata, and Whiston's astronomical diagrams were not mere supplements to the texts; to omit them would have disrupted an integrated visual and verbal mode of communication.[186] Illustrations therefore comprise a critical aspect of many written works, and are in no sense excluded by a reference to textual tradition so long as they remain intelligible to a careful reader without specialized, nontextual training. If a generally literate reader may come to understand a drawing without leaving an armchair (surrounded by a stack of books) then the visual language remains embedded in a textual tradition as described in Chapter 1.[187] Illustrations in Theories of the Earth were read by means of literary, emblematic, and artistic conventions which often originated within the earlier works of the tradition, but did not require prior specialized training on the part of an outsider to the tradition. This constraint worked to any Theorists' advantage because Theories of the Earth were by nature, as a textual tradition, directed

[185]Rudwick has noted that the use of exaggerated vertical scales continued in the nineteenth century, despite De la Beche's section: "The great vertical exaggeration that had been so heuristic in Cuvier and Brongniart's sections could easily become misleading if applied to sections of folded strata or topography of high relief. In his book of *Sections and Views* (1830), De la Beche recommended that wherever feasible traverse sections should be drawn at or near true scale (i.e., with the vertical scale the same as the horizontal), in order to avoid the danger of over-estimating the magnitude of the phenomena which geologists needed to explain in causal terms. He followed his own advice in the lengthy sections that were appended to his *Report on the Geology of Devonshire* (1839), the first-fruits of the new Geological Survey. But this sober empiricism tended to make the structure revealed by such sections difficult to interpret, and more diagrammatic sections with vertical exaggeration continued to be a popular form of illustration." "Visual Languages," 171; cf. *Devonian Controversy*, #. In the following paragraphs Rudwick describes the continued use in the nineteenth century of ideal or theoretical sections (local, not global). Textured globes produced today are more like Burnet's rough globe than De la Beche's, since to emphasize the roughness of the globe they are constructed with an exaggerated vertical scale. (A height of ten miles on a twelve-inch diameter globe would be equivalent to the thickness of only about two sheets of paper.)

[186]I owe the phrasing of this last sentence to Rudwick, "Visual Language," although Rudwick was referring to mid-nineteenth century stratigraphy (p. 152): "By about 1840, these forms of visual communication in geology no longer functioned as supplements to verbal description and verbal concepts; still less were they merely decorative in function. They had become an essential part of an integrated visual-and-verbal mode of communication."

[187]The OED offers a different definition of "text" as the "body of any treatise, the authoritative or formal part as distinguished from notes, appendices, introduction, and other explanatory or supplementary matter." (S.v. "text," definition 2, 17: 852.) On this overly-narrow definition, one might regard the multi-page pamphlets many 19th century artists provided in association with their paintings as being a textual tradition! Yet given a rich and historically complex etymology linking "text" to textiles and tapestries, one may hardly exclude visual elements from a written tradition. To use a substitute term such as "print tradition," with its connotation of stability, does not convey and indeed misrepresents the distinction between textual and technical traditions presented in Chapter 1.

beyond professional, disciplinary, institutional and scholarly boundaries, to an audience potentially as wide as the general reading public. For example, Whiston's geometrical constructions might seem to border on the technically esoteric for a general readership, but he took pains to instruct the reader in their interpretation. After devoting many pages in the beginning of the book to a tutorial on the diagrams, and introducing basic geometrical reasoning with circles and ellipses, he could be confident the reader knew how to interpret them when called upon to do so later in the work.[188] Additionally, of course, the drawings incorporated among their geometrical forms the physical (non-mathematical) and by-then conventional Cartesian-style Earth. Furthermore, the very presence of astronomical diagrams constituted a kind of "geometrical rhetoric" that urged the reader to admire the sophistication of the Newtonian mathematical methods the diagrams embodied, and to transfer that respect to the Newtonian Theory of the Earth which he claimed to present.

Eventually, with the emergence of geology in the early nineteenth century, geological maps became very difficult to understand unless one had direct experience of the kinds of landforms they represented in addition to prior training in the tacit conventions of the maps. Geological books and articles became tacitly linked to the fieldwork and laboratory techniques which they now only partially conveyed. The textual tradition of Theories of the Earth was partially displaced by and partially differentiated into associated technical disciplines as they matured.[189] This departure from a primarily textual character had numerous consequences for geology's conduct and content as a technical tradition of published inquiry directed toward a specialized audience. Given the contested nature of Theories of the Earth, a character which arose from the diverse technical, scholarly, and ideological interests of various

[188]That Whiston believed the basics of such diagrams had become familiar to the reader is reflected in his introduction of Figure 1: "Now verbal Descriptions in such cases being of small advantage, compar'd to Schemes and Graphical Delineations, I shall wave [*sic*] more words about it, and exhibit an intire Figure of the whole to the view and consideration of the Reader." Whiston, *New Theory*, 154. In this way my strategy in writing Part 1, of course, mirrors that of Whiston.

Theorists, visual elements played an important role in the forging of a common intellectual tradition of discourse and debate.

[189]For example, the development within Theories of the Earth of an incipient technical tradition of geognosy (and Huttonian geology) led to a transformation of the textual tradition of Theories of the Earth. Humboldt reflects this technical transformation when he defined geognosy as a science that is exclusive of the "theory of the Earth," which after geognosy matures, as he would have it, is left with only the remote origin of the Earth as its subject matter: "Positive geognosy has been enriched by all the discoveries that have been made on the mineral constitution of the globe, and furnishes valuable materials to another science, improperly called the *theory of the earth*, which comprehends the first history of the catastrophes of our planet. It reflects more light on that science than it receives in its turn; and without contesting the ancient fluidity or the softness of the stony beds, (a phenomenon proved by the fossil bodies, by the crystalline aspect of the masses, by the rolled pebbles, or the fragments imbedded in the transition and secondary rocks,) positive geognosy does not pronounce on the nature of the liquids in which it is said that the deposits were formed, those waters of granite, porphyry, and gypsum, which in hypothetic geology, are made to arrive tide by tide on the same point of the globe." Humboldt, *Geognostical Essay*, 67. Cf. page 45.

EPILOGUE

Transformations of a Tradition: From Genesis to History

Recapitulation

Jacques Roger argued that Theories of the Earth contributed to the development of historical sensibilities in natural science, and this dissertation establishes the need to reassess such a "Relevance Thesis" in a positive light. The three sections of this Epilogue each introduce a nineteenth-century work published in the generation after Cuvier which in some respect displays the continuing legacy of Theories of the Earth. One was written by a Scottish geologist (Daniel Mackintosh), one by a Swiss-American physical geographer (Arnold Guyot), and one by a respected polymath who for a time served as a Professor of Mineralogy at Cambridge and as a President of the Geological Society of London (William Whewell). These works are not discussed in their own right, but in order to recapitulate some important aspect of the tradition of Theories of the Earth pertaining to the Relevance Thesis.

The first section uses the Huttonian geology of Daniel Mackintosh to review the contrast between nondirectionalist temporal sensibilities and the Wernerian radiation discussed in the previous chapter. Selecting an obscure mid-century geologist to represent the continuing influence of Hutton's Theory of the Earth serves as an important reminder of the diversity of temporal sensibilities encompassed within Theories of the Earth, and of the complexity of their relations with early geological inquiry.

In this dissertation I have defended the main thesis of Jacques Roger while departing from his historiography. That is, I have argued that Theories of the Earth are best understood as a *textual tradition* delineated by internal and external textual criteria rather than defined as a mentality or metaphysical world-view. Coincidentally, I have defended Roger's sense of the importance of Descartes and Burnet in establishing a tradition of textual debate, despite arguing against Roger's insistence on the origin of the tradition as a post-Copernican mentality or genre of thought. As a textual tradition Theories of the Earth were *contingently* established with Descartes and the controversies over Burnet and sustained through the generation of Cuvier, rather than being the inexorable expression of post-Copernican cosmology, of a metaphysical world-view, or of a pre-geological genre of non-empirical speculation.[1] Furthermore, in recognition of their diversity I describe Theories of the Earth as a *contested* textual tradition in which experts representing diverse technical traditions participated rather than a unified, conceptually-continuous, intrinsically-coherent research program. If Theories of the Earth are recognized as a contested textual tradition then the agenda of sharply demarcating between Theories of the Earth and other texts before, during, or after the tradition (as in Rudwick's interpretation of Cuvier) becomes irrelevant, and many of the objections to a modest form of Roger's Relevance Thesis dissipate. The second section of this Epilogue reviews some

[1] In this respect my claim for the contingent development of historical sensibilities in the natural sciences resembles that of Cushing for the development of quantum theory: "The central theme of this book is that historical contingency plays an essential and ineliminable role in the construction and selection of a successful scientific theory...." James T. Cushing, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony* (Chicago: University of Chicago Press, 1994), xi.

of these characteristics of contested textual traditions as they were manifest in a work by William Whewell who, appropriating directionalist geology, articulated a thoroughly historical sensibility emphasizing the significance of contingent events.

In Part II I sketched a rough portrait of Theories of the Earth as a contested textual tradition on the basis of "reading" selected visual representations of the globe. Chapter 4 argued that in addition to being of interest in their own right, didactic global representations provide a suitable subject for analysis in the terms of textual traditions. At the same time they serve as a more representative sample of what Theories of the Earth were about than would a survey based upon a conceptual principle of selection. Chapter 5 provided a systematic reading of the illustrations involved in the establishment of the contested textual tradition. Chapter 6 surveyed snapshots of various technical transformations of the tradition. The didactic visual illustrations of the books used in this Epilogue are considered as well.

Taken together, the dissertation suggests that the language of biblical idiom sometimes fostered the expression of historical sensibilities in the tradition, although such idiom was never an essential characteristic of Theories of the Earth. At times hexameral idiom facilitated the interpretation of Earth history as an ordered succession of events (prehuman, sometimes historically-contingent, not necessarily ancient) on the basis of the coordinated reading of a variety of kinds of empirical evidence. The convergence of hexameral commentaries with Theories of the Earth is interesting in part because interpretations of the first chapter of Genesis were also a contested textual tradition. The final section of this Epilogue reviews the significance of hexameral idiom using the hexameral geology of Arnold Guyot and James Dwight Dana. The role of hexameral idiom in the tradition of Theories of the Earth supports a modest form of Roger's Relevance Thesis, consistent with other studies emphasizing the significance of historical scholarship, mineralogy and paleontology for the development of historical sensibilities. In sum, the Relevance Thesis of Jacques Roger may be cautiously reaffirmed without it being necessary to insist upon sharp discontinuities in either the origin or the demise of Theories of the Earth.

§ 1. Huttonian Sensibility: A Non-Historical Natural Order

Citing his fellow Scotsman the theologian Thomas Chalmers, the geologist Daniel Mackintosh (1815-1891) suggested that, having nothing to do with creation or the origin of the existing natural order, geology could not possibly conflict with Scripture.[2] To convey his Huttonian Theory of the Earth, Mackintosh included a didactic, hand-colored global section of the "revolutions of the earth's surface" (Figure 228). Contrary to the impression given by the section, he noted that the crust is a "comparatively thin rind":

> The adequacy of volcanos and earthquakes to give rise to such inequalities as those presented by the surface of the earth, has been doubted, but... the highest mountain bears no greater a proportion to the entire mass of the earth, than an asperity on the surface of an orange bears to the whole size of the orange.[3]

Figure 2, just above the section, reinforces this point by depicting the height of the Grampian mountains in a non-exaggerated vertical scale.

[2] Daniel Mackintosh, *A Key to Geology: Being a Cursory View of the Present State of Discovery regarding the Structure and Revolutions of the Earth* (Edinburgh: John Anderson; Glasgow: John MacLeod; London: Simpkin, Marshall & Co., 1839), 14. Morton describes Mackinstosh's career: "Daniel Mackintosh (1815-1891), son of a Scottish mill-worker, left Scotland for England when he was about 30 years old and lectured on Geology, Physical Geology, and Astronomy. For his later geological investigations, particularly his work on drift (glacial) deposits in northern England and Wales, Mackintosh was elected a Fellow of the Geological Society in 1861 and received a number of awards including the Geological Society's Lyell Fund in 1886." George H. Morton, "Daniel Mackintosh, F.G.S," *Geological Magazine*, 8 (1891): 432. The conservative Presbyterian Thomas Chalmers was an influential advocate for the plurality of worlds, and for the "gap" theory which posited an indefinite period of time between the original creation of the universe in Genesis 1:1 and the formation of the Earth beginning in Genesis 1:2. Cf. Thomas Chalmers, *A Series of Discourses on The Christian Revelation, Viewed in Connection with The Modern Astronomy*, 4th ed. (Glasgow: Printed for John Smith and Son, 1817).

[3] Mackintosh, *Key to Geology,* 4. For pictorial expression of similar views see page 587 (Whiston), Figure 226 (De la Beche) and Figure 227 on page 718 (Dana).

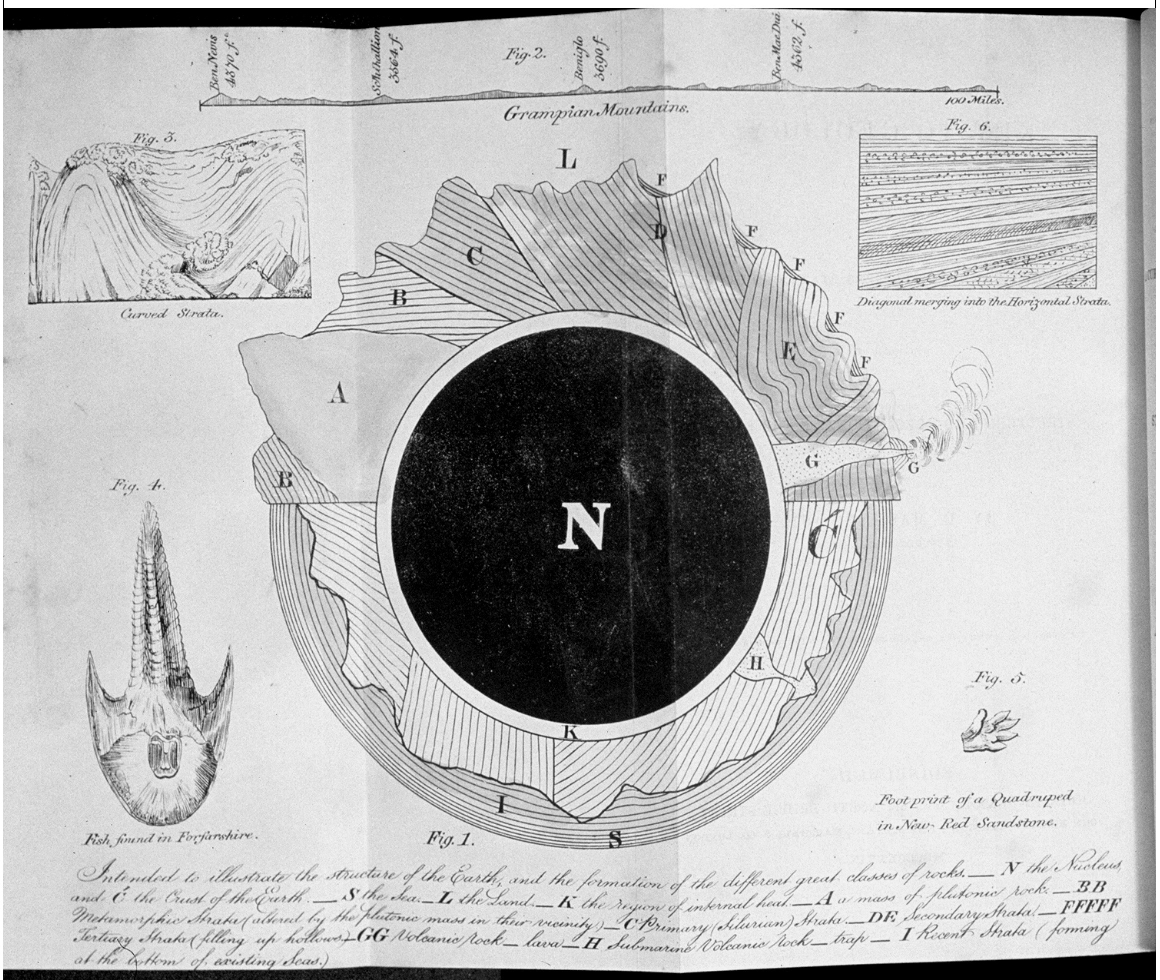

FIGURE 228. Mackintosh, *Fig. 1*: Huttonian colored global section "Intended to illustrate the structure of the Earth, and the formation of the different great classes of rocks." LH.

N = Nucleus (black)	A = mass of plutonic rock
C = Crust of the Earth (both seabed, lower half; and land, upper half)	B, B = Metamorphic strata altered by the plutonic mass in their vicinity.
S = Sea (horizontal strata)	C = Primary = Silurian strata.
L = Land (strata displaced from horizontal)	D, E = Secondary strata.
K = region of internal heat	F = Tertiary strata filling up hollows.
	G, G = Volcanic rock, lava.
	H = Volcanic rock, trap.
	I = Recent strata (forming at the bottom of existing oceans).

For Mackintosh, mountains were not elevated all at once, but over an "immeasurable lapse of duration, by a series of reiterated internal movements."[4] Stratified rocks are of aqueous origin (*e.g.,* Figure 228, *I*); nonstratified of igneous origin (*e.g.*, *A, G*). Plutonic rocks (*A* in Figure 228) originate by heat in all periods of Earth history, and are not stratified. (Mackintosh noted that granites discovered in Secondary formations disproved the "imaginary conjecture" that it was the oldest kind of rock.[5]) Volcanic rocks such as basalt, greenstone, trachyte, lava, and pumice rise upward, either to the surface above land (e.g., lava, *G*) or to the ocean floor (e.g., trap, *H*). Because of uplifts and dislocations, the older the rocks, the more likely they are to be inclined (compare the flexures of strata by lateral compression illustrated in *Fig. 3 "Curved Strata"* as observed near St. Abb's Head, Berwickshire). Following Ami Boué and Charles Lyell, Mackintosh regarded many of the older "primitive" rocks as metamorphically-altered younger strata, and restricted the term "Primary" to rocks of Silurian (possibly Cambrian) age (*e.g., C* in Figure 228).[6]

Mackintosh explained that the Secondary strata such as Mountain Limestone, the Old Red Sandstone and the Coal Measures are of more recent age, yet formed in the same way (*D, E*). The Old Red Sandstone, although thick in Scotland, contains few fossils except for remarkable fish like the *Cephalaspis* (*Fig. 4*). Despite the primitive appearance of these fish (championed by directionalists such as Louis Agassiz and Hugh Miller), Mackintosh emphasized the uniformity of causes: "Nothing perhaps can better convince one of the sameness of ancient and modern causes than an examination of a piece of old red sandstone conglomerate."[7]

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[4] Mackintosh, *Key to Geology,* 4.

[5] This rhetorical caricature is discussed above on page 38.

[6] "But ever since the so-termed primary strata were shewn to be mere altered aqueous deposits, and deposits some of which are referrible to the secondary period, the term primary as applied to them has gradually fallen into disuse. Mr Lyell, who is admitted to be the most eminent living Geologist, terms these strata metamorphic rocks; and following M. Boué, perhaps the most eminent living Continental Geologist, he has transferred the term primary to the ancient transition, or modern Silurian strata." Mackintosh, *Key to Geology,* 5.

[7] Mackintosh, *Key to Geology,* 6.

We have seen that to the Huttonian sensibility, the accidents of history play no constitutive role in the system of the Earth.[8] If the natural order is shorn of historical contingency, then the hexameral account (interpreted as pertaining to contingencies) could be divorced from natural inquiry, as in the "gap" theory of Thomas Chalmers which relegated the first verse of Genesis to an unknowable originative moment and confined the remainder of the chapter to a geologically-irrelevant restricted place and time.[9] The Huttonian rock cycle served Mackintosh as the empirical foundation for his nondirectionalist perspective of a functional system of the Earth, an "inflexible" and "fixed" natural order which reveals no trace of a contingent origin:

> Such are the revolutions of the planet on which we dwell. They exhibit *no symptoms of a commencement—no signs of a termination!* At every period of the earth's history they are the same, governed by laws which never fluctuate, regulated by principles *as inflexible as decree, and fixed as predestination*. In existing changes we only perceive a perpetuation of former changes; and in the latter we see a type of vicissitudes that are to come. Geology penetrates no farther into the future than existing operations, and the relation between them and their effects, enable us: no deeper into the maze of past time than there are monuments beneath our feet to guide us.[10]

Paradoxically, given Hutton's usage of "Theory of the Earth" to refer only to the operations of the present natural order, geologists of Huttonian and other persuasions sometimes constructed boundaries for their newly-matured technical discipline of geology by defining "Theory of the Earth" as referring only to the less reliable inferences of a less mature science dealing

[8] See the overview of Hutton's Theory of the Earth in "Hutton and the Whig Interpretation of Geology," beginning on page 269. For Hutton's denial of the significance and intelligibility of historical contingency, and his assertion that habitability serves as the final cause of the Earth, see the quotation on page 326. For a description of various temporal sensibilities and a definition of terms see "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

[9] For Chalmer's gap theory see footnote 2 on page 725. On the other hand, to interpret the hexameral account within a directionalist sensibility might raise the possibility of historical contingency at the very foundation of the natural order, as in Hugh Miller, *The Old Red Sandstone; or, New Walks in an Old Field*, From the Fourth London Edition (Boston: Gould and Lincoln, 1857). Miller's *Old Red Sandstone* devoted considerable space to historical interpretations of the primitive fossil fish.

[10] Mackintosh, *Key to Geology,* 13; italics added. Note that the first emphasized phrase directly echoes Hutton's phrase, "no vestige of a beginning, no prospect of an end," discussed above on page 274.

only with the remote, original formation of the globe.[11] Restricting the scope of Theories of the Earth in this way, Mackintosh described the scope of geology:

> It has nothing to do with fancies and reveries respecting creation, or the original condition of the earth. It does not even investigate causes, strictly so called. Like the philosophy of Newton, it only examines immutable laws, and traces the relations between these laws and the formation of certain phænomena. 'It is,' in the words of the gifted Hutton, 'in nowise concerned with questions as to the origins of things.'[12]

Thus Mackintosh deployed the Huttonian Theory and Newtonian phenomenalism to defend a posture of agnosticism toward a scientific knowledge of origins.[13] In its emphasis on stability, perpetual habitability, and lack of a meaningful formative past, Huttonian Theory was no more historical than the older Aristotelian cosmology and meteorology. In commenting on the Coal Measures Mackintosh explicitly declared his opposition to directionalist interpretations: "there exists no real ground for supposing that, at the carboniferous æra, geological conditions were, as a whole, any dissimilar to those of modern times."[14] Just as Fitton regarded Lyell as having updated the Huttonian Theory of the Earth, so Mackintosh exulted in Hutton's temporal sensibility, interpreting the Coal Measures in a non-directionalist perspective much like Lyell's inference about the uniformity of conditions in a future Carboniferous Period.[15]

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[11] The example of Alexander von Humboldt and geognosy is discussed in footnote 189 on page 721; cf. page 45.

[12] Mackintosh, *Key to Geology,* 13.

[13] Phenomenalism and causal knowledge are discussed in "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

[14] Mackintosh, *Key to Geology,* 6. "Directionalism" does not refer to "directed" or "direction" in a teleological sense (for Hutton's Theory of the Earth was in many ways more teleological than the directionalist alternatives, with a system of the Earth designed to perpetuate human habitability). For a definition of "directionalism," "non-directionalism" and other temporal sensibilities see "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

[15] Lyell suggested that "Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanadon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyle might flit again through umbrageous groves of tree-ferns." Charles Lyell, *Principles of Geology* (1830), volume 1. For this passage and contemporary reaction to it see footnote 49 on page 285.

§ 2. Historical Sensibilities in a Convergence of Textual Traditions: William Whewell and the Plurality of Worlds

The nondirectionalist perspectives of Mackintosh and Lyell, in some manner a legacy of Hutton's Theory of the Earth, make an interesting contrast to contemporaries whose historical sensibilities were also shaped by the textual tradition of Theories of the Earth. As already noted, de la Beche caricatured Lyell's *Principles* because of its patently implausible anti-directionalism.[16] To conclude, we briefly consider the convergence of textual traditions and directionalist historical sensibilities exemplified by William Whewell, Arnold Guyot, and James Dwight Dana.

We have seen that to regard Theories of the Earth as a contested textual tradition does not mean that they put insufficient emphasis upon empirical evidence or technical expertise.[17] Composed of diverse audiences overlapping in complex relations, any contested textual tradition depends upon the translation of technical expertise into multidisciplinary discourse, and when such translation slackens, the tradition fades or declines into folk-science vestiges.[18] Nor were textual traditions mere popularizations rather than contributions to knowledge; rather, they could play a substantive role by stimulating and shaping technical investigations in participating disciplines (a process here referred to as "technical naturalization").[19] In the same way, for example, William Whewell's essay on a plurality of worlds was not just a popularization, but contributed to important methodological discussions as well as ongoing investigations in astronomy and cosmology.[20] Thus processes of translation and nat-

[16] On Lyell and De la Beche see the reference in footnote 15.

[17] This influential Baconian view (e.g., that the rise of modern science occurred as a result of studying things instead of reading texts) was critiqued in "Natural Knowledge and Textual Traditions," beginning on page 66.

[18] For a description of the process of "Translation" in textual traditions, see "Appropriation Model: An Alternative to Marginality," beginning on page 341.

[19] Some relations between textual traditions and popular science are examined in "Textual versus Technical Traditions," beginning on page 79. For a description of the process of "Technical Naturalization" in textual traditions see the discussion accompanying Table 42, "Appropriation Model for Theories of the Earth," on page 342.

uralization sustained the similar contested textual tradition of Plurality of Worlds, and we have seen that its topics and readership often overlapped with Theories of the Earth.[21]

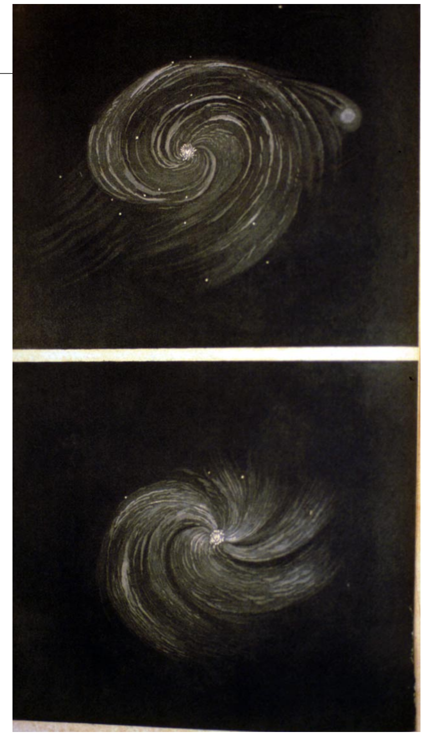

FIGURE 229. Whewell, *Plurality of Worlds* (1856), frontispiece. HSCI.

In two chapters of *The Plurality of Worlds* (1853) that together may be regarded as a theory of the Earth, William Whewell (1794–1866) argued against the natural theology of Scottish theologian Thomas Chalmers and the evolutionary materialism of Robert Chambers' *Vestiges of the Natural History of Creation* (1844) by denying the likely existence of extraterrestrial life.[22] Whewell wrote that from geology, "perhaps, we may obtain some knowledge of the place of the earth in the scheme of creation—how far it is, in its present condition, a thing unique, or only one thing among many like it."[23] Inevitably, perhaps, in this mid-nineteenth century debate in the Plurality of Worlds tradition, argu-

[20] Crowe comments that "by their use of weak analogies and their readiness to speculate on flimsy evidences, [the pluralists] had provided him with a field day. Having rejected their metaphysical and theological arguments for pluralism, Whewell was able to see that many of their astronomical claims were extremely weak. Whewell was, after all, correct in believing the solar system bereft of higher forms of life beyond the earth, and he was justified in doubting that stars are in every case encircled by habitable planets. Nor did he err in questioning that all nebulae are resolvable into stars, as Huggins soon showed. Moreover, whatever the merits of the theological position that motivated his attack, he no doubt made some pluralist astronomers see the frailty of their conjectures." Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge: Cambridge University Press, 1986), 288. Crowe argues repeatedly that Whewell's essay influenced technical astronomy (e.g., pp. 286–287).

[21] The overlap between Theories of the Earth and Plurality of Worlds is emphasized in "Textual Criterion 2: Participation in a Common Debate," beginning on page 139, and "Cartesian Cosmogonies," beginning on page 557.

[22] William Whewell, *Of the Plurality of Worlds: An Essay. Also, A Dialogue on the Same Subject*, 2d ed. (London: John W. Parker and Son, 1854). This episode is analyzed by Michael J. Crowe, *The Extraterrestrial Life Debate, 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell* (Cambridge: Cambridge University Press, 1986); and John Hedley Brooke, "Natural Theology and the Plurality of Worlds: Observations on the Brewster-Whewell Debate," *Annals of Science* 34 (1977): 221–286.

[23] Whewell, *Plurality of Worlds*, 73. Similarly (p. 84): "...the history of the world, and its place in the universe, are far more clearly learnt from geology than from astronomy."

ments on all sides exposed nonempirical precommitments underlying different temporal sensibilities and different areas of technical expertise. Whewell's argument is especially interesting in the way he deployed a thoroughly directionalist-historical perspective of Earth history as a foundational assumption to regulate inferences about the abundance of intelligent life on other worlds. Specifically directed against Hutton, Whewell advanced his "Argument from Geology" (the title of chapter 6) for a vast succession of creatures over immense ages of the world, with the appearance of human habitation "very brief and limited" in an "atom of time."[24] If the vast length of the history of the Earth could be void of intelligent life, then why must the vast reaches of space be filled with such life?[25] Such a plenary distribution is refuted temporally in the case of the Earth, which we know, so how can it be assumed to hold spatially for other worlds, of which we have no knowledge?[26]

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[24] "Here then we are brought to the view which, it would seem, offers a complete reply to the difficulty, which astronomical discoveries appeared to place in the way of religion:—the difficulty of the opinion that man, occupying this speck of earth, which is but as an atom in the Universe, surrounded by millions of other globes, larger, and, to appearance, nobler than that which he inhabits, should be the object of the peculiar care and guardianship, of the favor and government, of the Creator of All, in the way in which Religion teaches us that He is. For we find that man, (the human race, from its first origin till now,) has occupied but an atom of time, as he has occupied but an atom of space:—that as he is surrounded by myriads of globes which may, like this, be the habitations of living things, so he has been preceded, on this earth, by myriads of generations of living things, not possibly or probably only, but certainly; and yet that, comparing his history with theirs, he has been, certainly has been fitted to be, the object of the care and guardianship, of the favor and government, of the Master and Governor of All, in a manner entirely different from anything which it is possible to believe with regard to the countless generations of brute creatures which had gone before him. If we will doubt or overlook the difference between man and brutes, the difficulty of ascribing to man peculiar privileges, is made as great as by the revelations of geology, as of astronomy. The scale of man's insignificance is, as we have said, of the same order in reference to time, as to space. . . . . If the earth, as the habitation of man, is a speck in the midst of an infinity of space, the earth, as the habitation of man, is also a speck at the end of an infinity of time. If we are as nothing in the surrounding universe, we are as nothing in the elapsed eternity; or rather, in the elapsed organic antiquity, during which the earth has existed and been the abode of life. . . . If the planets *may* be the seats of life, we know that the seas which have given birth to our mountains *were* the seats of life. . . ." Whewell, *Plurality of Worlds*, 121–122; underlining added.

[25] Whewell, *Plurality of Worlds*, 124: "Or is the objection this; that if we suppose the earth only to be occupied by inhabitants, all the other globes of the universe are wasted;—turned to no purpose? Is waste of this kind considered as unsuited to the character of the Creator? But here again, we have the like waste, in the occupation of the earth."

[26] "If such an astronomical analogy be insisted on, we must again have recourse to geology, to see what such analogy is worth. And then, we are led to reflect, that if we were to follow such analogies, we should be led to suppose that all the successive periods of the earth's history were occupied with life of the same order; that as the earth, in its present condition, is the seat of an intelligent population, so must it have been, in all former conditions." Whewell, *Plurality of Worlds*, 127.

Whewell's arguments were antithetical to the general providence and nondirectionalism of Huttonian sensibilities, and invalidate occasional characterizations of Whewell as a semi-deist. Rather, they reflect a voluntarist theology of particular providences and contingent events and were based on a directionalist sensibility of Earth history.[27] Consistent with Whewell's phenomenalist epistemic aims, he held open the occurrence of miracles not dogmatically, but in a way that allowed for contingency.[28] Whewell held that the progress of Earth history was not necessary; even the eventual appearance of humans, despite their importance in the design of providence, could not have been predicted in advance.[29] Whewell's deployment of particular providence expressed a sense of divine dominion governing both general regularities and specific events, rather than the sufficiency of law; in support he cited Isaac Newton's General Scholium.[30]

Widely discussed and intensely contested, Whewell's interdisciplinary text is a clear instance of translation from a technical into a textual tradition according to the adaptation of Sabra's model described in Part I, page 342. For this reason his chapter on the "Argument from Geology" may be considered as a theory of the Earth, as already noted.[31] Textual traditions cannot be defined by any set of essential conceptual features, but must be delineated by

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27 Citing the well-known passage from Whewell that Darwin used as an epigraph for *On the Origin of Species* (1859), James Moore refers to Whewell's emphasis on general providence, that design is best understood as referring to general laws, as semi-deist. Brooke argues that Whewell devised his anti-pluralist arguments in opposition to the materialist evolutionism of *Vestiges*, which no doubt played a critical role in prompting Whewell's re-evaluation of his former pluralist beliefs. However, on the basis of previously unpublished documents, Crowe persuasively shows that Whewell's conversion to an anti-pluralist position derived from personal theological concerns, particularly difficulties reconciling his Trinitarian and Incarnational beliefs with the natural theology of Thomas Chalmers. See Crowe, 293. (References are in footnote 22.)

28 Cf. the analysis of Whewell's contribution to the Bridgewater Treatises in Crowe, *The Extraterrestrial Life Debate,* chapters 5-7.

29 Whewell, 274; cf. discussion in Crowe, *The Extraterrestrial Life Debate*, 292.

30 Crowe, *The Extraterrestrial Life Debate,* 279.

31 A modern example of a similar strategy is Peter D. Ward and Donald Brownlee, *Rare Earth: Why Complex Life is Uncommon in the Universe* (New York: Copernicus, 2000). Ward, a geologist, and Brownlee, an astronomer, present their arguments as an application of the historical sensibility presented in Gould's *Wonderful Life* against the kind of position popularized by Carl Sagan (or Star Wars, which took place long, long ago, not completely unlike Professor Ichthyosaurus' humans). Ward and Brownlee do not mention Whewell as an intellectual forebear or discuss at any length the history of the extraterrestrial life debate.

textual criteria of self-attribution, participation, or external attribution.[32] Whewell's text meets these criteria rather well. For example, with respect to the first criterion, of self-attribution, the text as a whole is primarily identified as a contribution to the Plurality of Worlds tradition against Chalmers (the same text cited by Mackintosh in his Huttonian geology). Yet these two chapters were specifically designated as an argument about Earth history. The second criterion of participation makes a stronger case because, in addition to Chalmers, Whewell also wrote in answer to Hutton and to the *Vestiges*.[33] Nor was this Whewell's first deployment of analogies between Earth history and the plurality of worlds: in 1827 Whewell, then a pluralist in agreement with Chalmers, argued that animal extinction and an ancient Earth posed no problem for Christians, for if astronomers routinely countenance the existence of unfamiliar life forms on other planets throughout the universe, so geologists should be permitted to suppose the existence of unfamiliar life forms during distant epochs in the history of the Earth.[34] The third criterion, external attribution, fits well, for Whewell's text was debated among many geologists and sometimes seen as relevant to their work. So were these two chapters a theory of the Earth in a timeless, generic sense, or a Theory of the Earth descending with modification from the population of texts comprising a recognizable tradition from Descartes to Cuvier? In this dissertation we have attempted to preserve a sense of ambiguity, to transcend such demarcation questions by employing textual criteria to delineate a tradition rather than conceptual criteria to define it according to allegedly-essential characteristics. By textual criteria Whewell's theory of the Earth bears several definite historical relations with the tradition of Theories of the Earth, but in Whewell's post-Cuvierian generation the once-com-

[32] For textual criteria see Table 10, "Textual criteria for participation in Theories of the Earth," on page 106. An informed diachronic perspective is necessary in order to avoid caricatures of Theories of the Earth, caricatures which otherwise almost inevitably intrude in synchronic monographs. In this study vignettes organized thematically (chapters of Part I, sections of Chapter 6) or chronologically (Chapter 5) allow only mere hints and suggestions toward the much needed studies of social contexts and historical settings. Cf. the discussions of diachronic studies on page 94ff. and of "big picture" thinking on page 203.

[33] That Chambers' *Vestiges* may be regarded as a Theory of the Earth is suggested above, page 302ff.

[34] Crowe, *The Extraterrestrial Life Debate*, 268. For Whewell's earlier agreements with Chalmers see Crowe, 267.

plex tradition appears to be in relative subsidence (at least in England). However, Whewell's chapters were clearly offered as a contribution to a textual tradition, and not as a species of geology *per se*. Whewell's geological arguments exemplify the heterogeneity of temporal sensibilities debated in the contested textual tradition of the Plurality of Worlds; an analogous heterogeneity characterized the textual tradition of Theories of the Earth. Nor did homogeneity on such issues prevail within more technical spheres of discourse, either; among technical geologists, few of Whewell's contemporaries agreed with his conclusions or held to as thoroughly developed a sense of the significance of contingency in the history of the Earth. Even Hugh Miller sided with Chalmers' pluralism against the conclusions of Whewell, although sometimes he employed similar lines of reasoning about the significance of contingent events in the history of the Earth. Temporal sensibilities were always complex, and it is never possible, either during or after Theories of the Earth, to specify a fixed or homogenous end-point. A fully historical sensibility was not generated in a predictable progression from Descartes' initial formulation of a cosmogonical Theory in the seventeenth century to the emergence of geology in the first half of the nineteenth century through the efforts of the Geological Society of London. Interestingly, however, one of Whewell's contemporaries who did share a similar sense of contingency was Charles Darwin, although Darwin spurned Whewell's extrinsic teleology. Whewell's underlying sense of particular providence was shared by Darwin's American defenders, Asa Gray and George Frederick Wright, however, and it facilitated their full embrace of Darwin's theory of evolution by means of natural selection. As Osler comments:

> Evolution does not have a predictable and determinate course of a kind that can be known by a priori and deductive methods. The metaphysical assumptions underlying this style of evolutionary science can be traced back to a voluntarist interpretation of the biblical worldview. Although theological language has dropped out of scientific discourse, contemporary styles of science are historically linked to the dialectic of the absolute and ordained powers of God. The interplay between necessity and contingency in the world is now constructed in entirely naturalistic terms, but it grew from roots embedded in an earlier, theological understanding.[35]

§ 3. From Genesis to History: Arnold Guyot, James Dana, and Hexameral Geology

The chapters of Part II show that temporal interpretations of Genesis 1 facilitated the assimilation of developmental perspectives of the Earth and cosmos. The fact that young-Earth creationism had to be re-invented in the twentieth century, according to Numbers, is evidence that hexameral idiom did not drop out of circulation in the nineteenth century.[36] We will not pursue the matter here, but to summarize the significance of hexameral idiom (and to suggest its staying power) consider one nineteenth-century example of hexameral illustration.

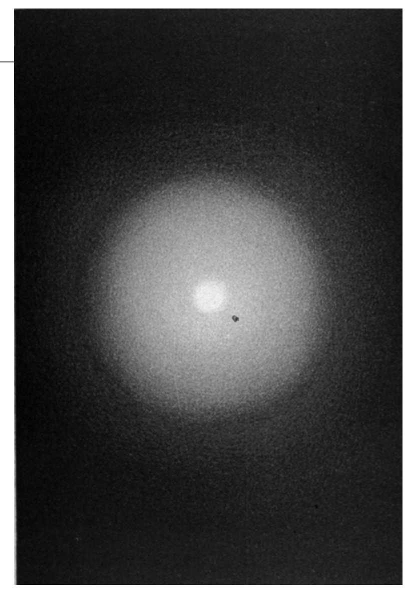

FIGURE 230. Guyot, *Creation* (1884). *Plate I.* Frontispiece. Primitive nebula. HSCI.

Explanation. Day 1. "Let there be light!" The beginning or activity of matter.

The Swiss naturalist and geographer Arnold Guyot (1807–1884) was a colleague of Louis Agassiz and an early convert to glacial theories. He was quite influential in persuading prominent American Presbyterians and Congregationalists (such as Charles Hodge) to accept day-age interpretations of Genesis. His arguments reached a wide audience in a series of articles in the journal *Bibliotheca Sacra*, and were later republished in a variety of forms including an illustrated volume entitled *Creation* (1884).[37] Guyot's hexameral interpretation was adopted by the American geologist James Dwight Dana and published

[35] Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994), 236.

[36] Ronald L. Numbers, *The Creationists: The Evolution of Scientific Creationism* (New York: Alfred A. Knopf, 1992).

[37] Arnold Guyot, *Creation, or, The Biblical Cosmogony in the Light of Modern Science* (New York: Scribner's, 1884).

in his successful textbook, the *Manual of Geology* (1863).[38] Even William Gladstone adopted Guyot's day-age interpretation from Dana in a polemical essay against German higher critics, which precipitated a vociferous rebuttal from Thomas Henry Huxley.[39]

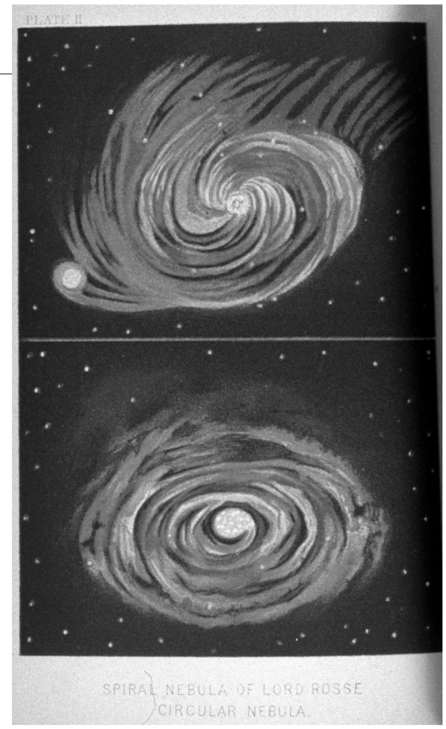

FIGURE 231. Guyot, *Creation* (1884). *Plate II*. "Spiral Nebula of Lord Rosse" (above) and "Circular Nebula" (below). HSCI.

Explanation. Day 2: The firmament dividing the waters. Nebulae were interpreted as cosmogonic systems in which the dividing and subdividing of the original fluid produces planets and other bodies.

Integrating landscape scenes with global views (Figure 232) and cosmic sections (Figure 230, Figure 231), Guyot's text resembles a nineteenth-century updating of Scheuchzer's hexameral scenes (see Appendix). From Descartes to Scheuchzer to Guyot, it is surprising how pervasive the hexameral tradition was. Hexameral discourse served as a major framework for interpreting all kinds of evidence, whether from astronomy, mineralogy, mathematical physics, natural history, or paleontology. In this sense hexameral idiom, particularly discussions of the third day, provided a "boundary object" by which practitioners of various disciplines and discourses could debate and dialogue with each other.[40]

Besides the fact that hexameral idiom promoted the conceptualization of the Earth as an ordered body, and helped to legitimize discussion of Earth's origins, the chief significance of

[38] James Dwight Dana, *Manual of Geology: Treating of the Principles of the Science with special reference to American Geological History, for the use of Colleges, Academies, and Schools of Science* (Philadelphia: Theodore Bliss & Co., 1863). 741–746.

[39] A brief account of the Gladstone-Huxley exchange is found in Adrian Desmond, *Huxley: From Devil's Disciple to Evolution's High Priest* (Reading, Massachusetts: Addison-Wesley Publishing Company, 1994,1997), chapter 27.

[40] "Boundary objects" are discussed in "Textual versus Technical Traditions," beginning on page 79.

the post-Renaissance hexameral tradition is that it suggested a linear history for the Earth, a non-instantaneous origin of the Earth through a succession of particular events, in contrast to a steady-state or cyclic view of creation. Martin Rudwick comments:

> In retrospect, perhaps the most significant feature of biblical illustrations such as Scheuchzer's was that they depicted a *sequence* of events in a temporal drama that had direction and meaning built into its structure. That model or precedent was therefore available to a later generation that sought to depict a comparable plot for far more ancient time and history.[41]

This observation elucidates Jacques Roger's suggestion that early modern biblical culture was one of the contextual pre-requisites for directionalist Theories of the Earth.[42] Rudwick comments that in contrast to natural history illustrations, scenes from deep time "could not be witnessed by any human beings at all":

> Here, significantly, the only precedent that might have been helpful was one with which many nineteenth-century 'men of science' were reluctant to be associated. Traditional biblical illustrations had always included scenes from the very beginning of time, before any human beings were present to record the events depicted.[43]

Most hexameral geogonic sections, global views, and landscape scenes (such as Scheuchzer's) were depictions of prehuman events. The candidates for possible observers of such scenes included not only the Creator, but also Burnet's cherubim, Whiston's unidentified human observer hovering over the still-forming surface of the Earth (perhaps the pre-Incarnate Christ), or Thomas Dick's extraterrestrials.

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41 *Scenes from Deep Time*, 26.

42 Roger commented that "pour le XVIIe siècle, le récit mosaïque était le seul modèle possible d'une histoire de l'univers et de la Terre...," Roger, "La théorie de la terre," 32. See "Roger's Demarcationist Criteria: Global Directionalism," beginning on page 211.

43 *Scenes from Deep Time*, 228.

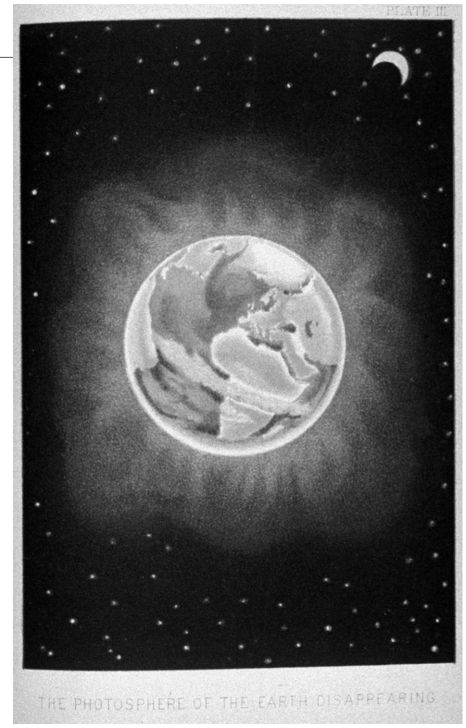

FIGURE 232. Guyot, *Creation* (1884). *Plate III*. "The Photosphere of the Earth Disappearing." HSCI.

Explanation. Day 3: Production of oceans and continents, including marine beds. This is the Azoic age, before animal life, the only period of truly universal formations. Day 4: Vapors condense and the atmosphere clears so that the stars and Moon become visible. Thus the second organic triad of days begins with light, just as did the first inorganic triad.

Depending on whether the deluge recapitulated the creation week in whole or in part, the processes recounted in the Earth's origin might or might not be reversible, and might or might not remain active to some degree today. The succession of events in the Earth's past might be investigated and discovered through a process of comparing and collating the textual clues given in the hexameral account with the empirical clues obtained from reading the book of nature.[44] The events of the creation week were regarded by Theorists from Steno to Guyot as intelligibly ordered despite being neither fully predictable nor deducible from first causes. More than the outcome of a genetic development from a given set of initial conditions, the natural order resulted from natural processes in combination with multiple interpositions of contingent events.[45] Thus Genesis 1 provided specific information about the historical contingency underlying the natural order, these writers believed, which aided the interpretation of the rocks and formations themselves.[46] When writers appealed to supernatural revelation, they also argued that both books were necessary. Reading the rocks in light of the riddle of the days required the correla-

[44] Dana captured this synchronized reading of the twin books: "The central thought of each step in the Scripture cosmogony—for example, Light—the dividing of the fluid earth from the fluid around it, individualizing the earth,—the arrangement of its land and water,—vegetation,—and so on—is brought out in the simple and natural style of a sublime intellect, wise for its times, but unversed in the depths of science which the future was to reveal." *Manual of Geology*, 744. See the discussion of the two-books metaphor in "Textual versus Technical Traditions," beginning on page 79.

[45] For definitions see "What is a Historical Sensibility? A Taxonomy of Temporal Terms," beginning on page 22.

tion of evidence from multiple sources, including ancient records and geological fieldwork. The pervasiveness of hexameral idiom habituated readers to acts of historical reconstruction rather than purely *a priori* deductive reasoning.[47]

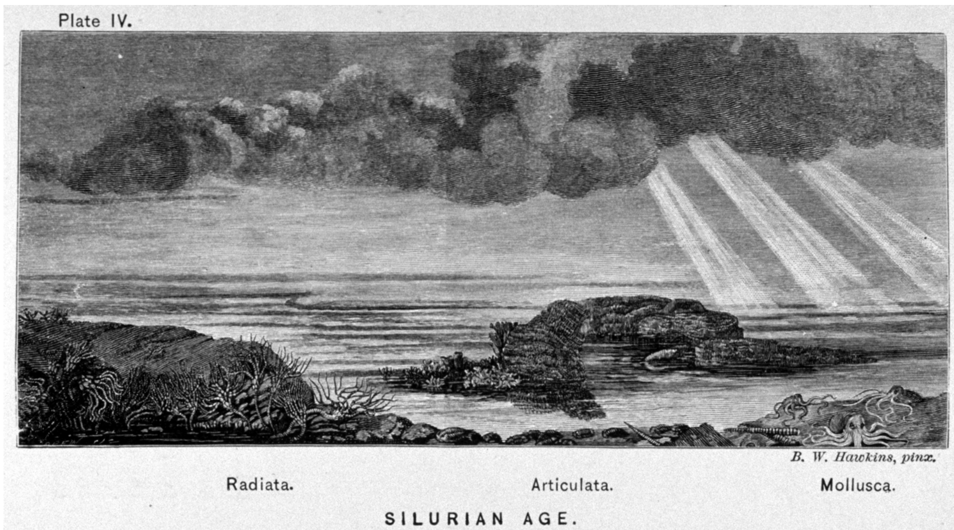

FIGURE 233. Guyot, *Creation* (1884). *Plate IV.* "Silurian Age," with radiata, articulata, and mollusca. HSCI. Day 5: Creation of the lower orders of animals.

We have seen that the Burnet controversy was fueled in part by Burnet's radical reinterpretation of the hexameron, while those like Scheuchzer, Whiston, Eaton or Guyot who sought to uphold the authority of the creation account ended up with novel re-interpretations. The hexameral tradition, like Burnetian global sections, proved surprisingly malleable in their hands.[48] In the same way, Guyot's hexameral interpretation appropriated the discoveries of contemporary geology wholesale, including Cuvier's fossil reconstructions (e.g., Figure 237) and Agassiz' fossil fish (Figure 234).[49]

[46] Dana commented on the hexameral account: "In this succession, we observe not merely an order of events, like that deduced from science; there is a system in the arrangement, and a far-reaching prophecy, to which philosophy could not have attained, however instructed." *Manual of Geology*, 745.

[47] The synchronized reading of the two books sometimes applied to those who denied special revelation but nevertheless accorded respect to scripture as an ancient text; see the discussion of Whitehurst on page 669.

[48] This accords with Grafton's assessment of the authority of ancient texts in early modern natural knowledge; cf. page 75.

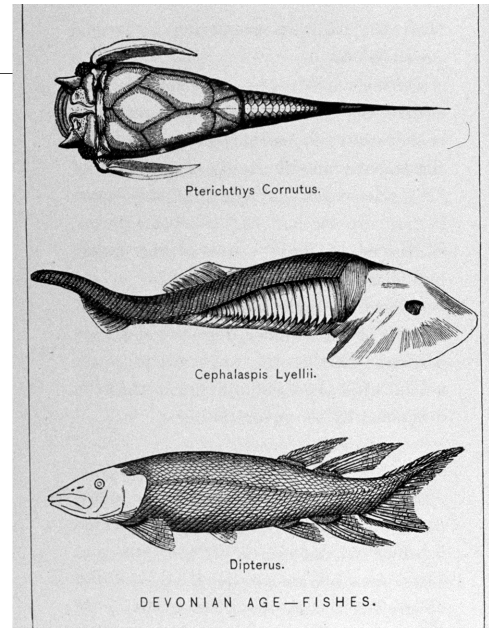

FIGURE 234. Guyot, *Creation* (1884). *Plate V.* "Devonian Age—Fishes." HSCI.

Explanation. Day 5: Marine animals fill the lower waters.

For geologists like Eaton, Guyot or Dana who utilized hexameral idiom, the temporal aspects remained paramount. Day-age interpretations of Genesis sanctioned the practice of geology as more than an elucidation of structural relations. Dana's attitude is typical in this respect:

> Geology is sometimes defined as the science of the structure of the earth. But the ideas of structure and origin of structure are inseparably connected, and in all geological investigations they go together. Geology had its very beginning and essence in the idea that rocks were made through secondary causes; and its great aim has ever been to study structure in order to comprehend the earth's history. The science, therefore, is a historical science.[50]

Without implying that hexameral idiom was more important for the development of historical sensibilities than other contexts such as paleontology, meteorology, mineralogy, antiquarianism, classical scholarship, or Romanticism, this study suggests that the language of Genesis 1 at times disposed practitioners to think in terms of historical succession and assisted the widespread discussion and assimilation of historical perspectives as they were developed on the basis of a variety of kinds of evidence.

[49] Contrast Cuvier's tendentious rhetoric about his predecessor's use of hexameral idiom, discussed on page 45 (cf. "Controversy and the Rhetoric of Demarcation," beginning on page 307).

[50] Dana, *Manual of Geology*, 4.

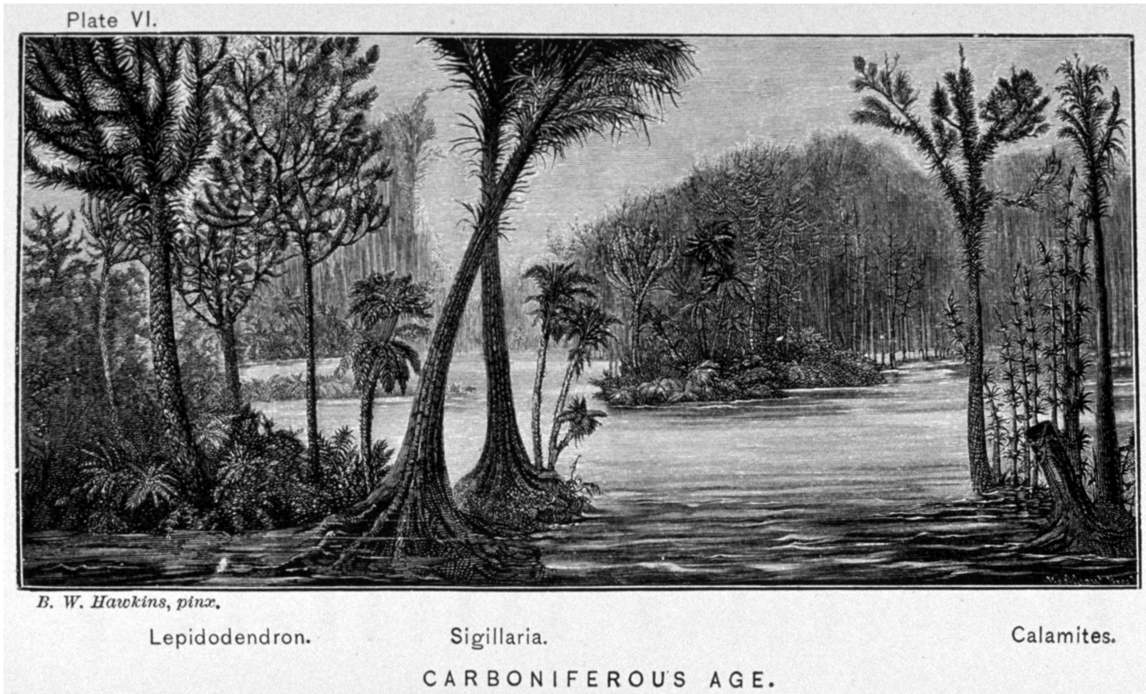

FIGURE 235. Guyot, *Creation* (1884). *Plate VI*. "Carboniferous Age." HSCI.

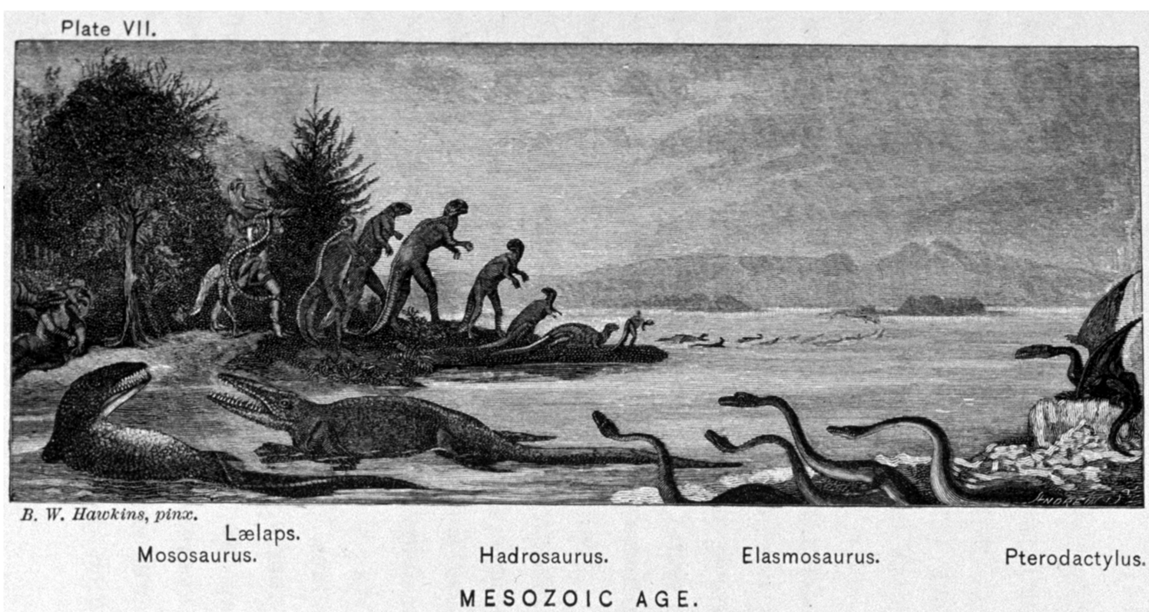

FIGURE 236. Guyot, *Creation* (1884). *Plate VII*. "Mesozoic Age." HSCI.

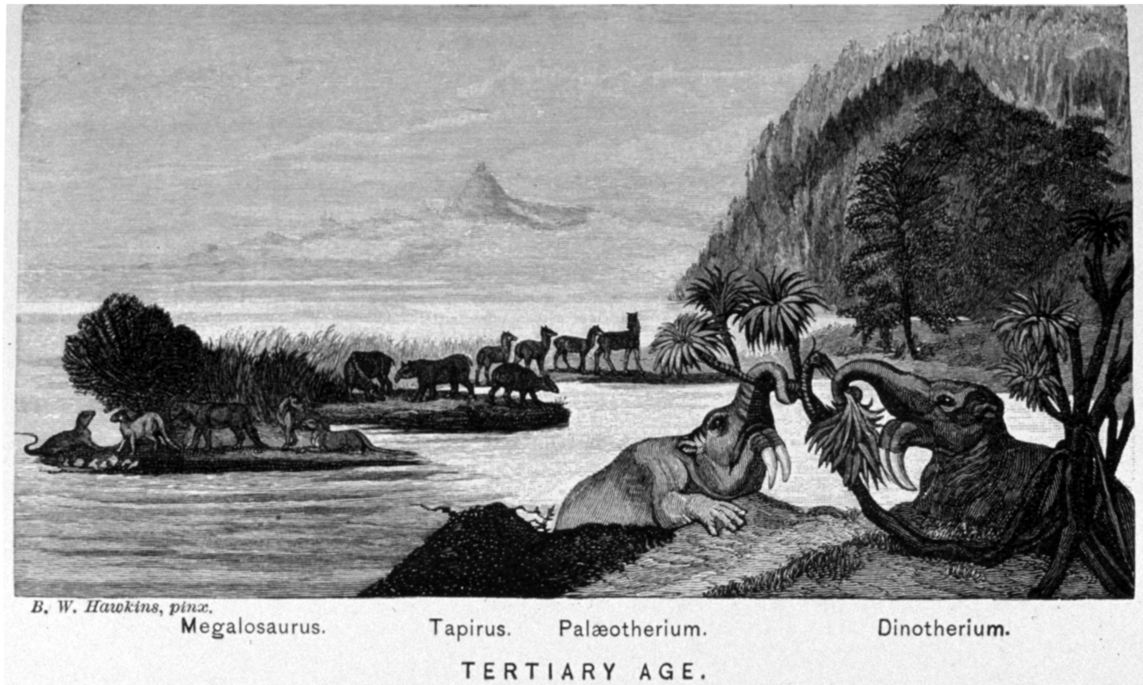

FIGURE 237. Guyot, *Creation* (1884). *Plate VIII*. "Tertiary Age" with Megalosaurus, Tapirus, Palaeotherium, and Dinotherium. HSCI. Day 6: Creation of mammals.

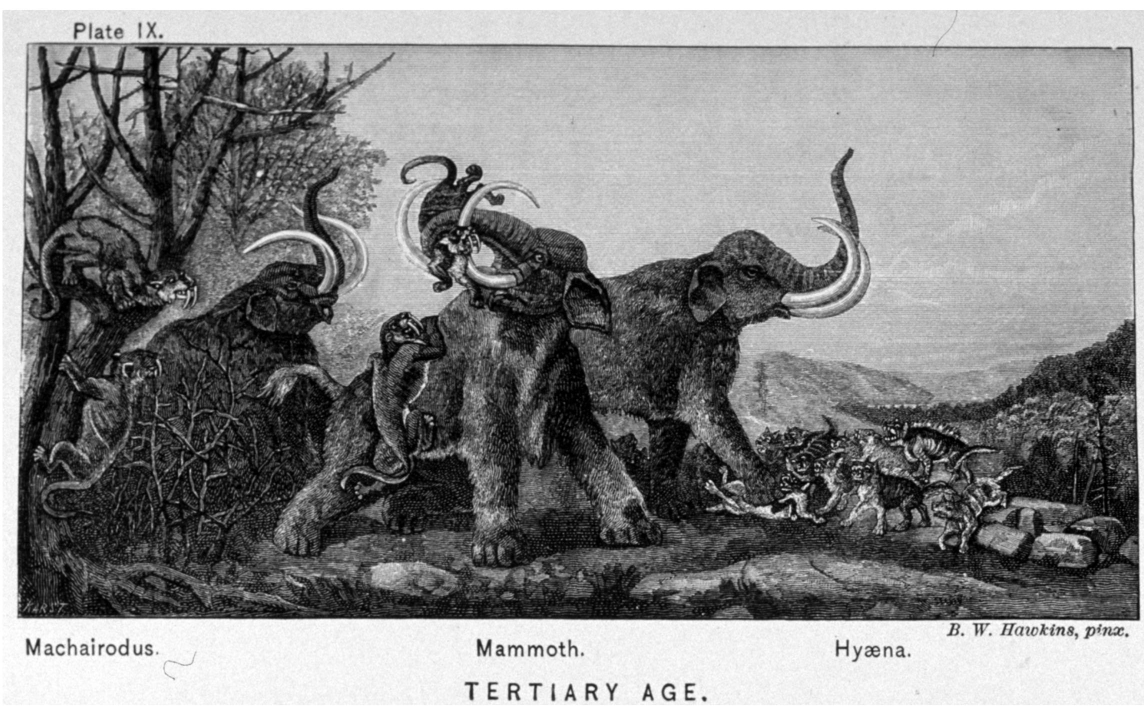

FIGURE 238. Guyot, *Creation* (1884). *Plate IX*. "Tertiary Age," with Machairodus, Mammoth, and Hyaena.

Any historical study touching upon the emergence of geology, the development of historical sensibilities, and the significance of visual representations must at every step interact with the prodigious scholarship of Martin Rudwick. Guyot's five hexameral landscape scenes (Figure 233, 235–238), at one end of the often-crossed bridge between didactic global and regional illustrations,[51] bring us to the center of the issues examined in Rudwick's *Scenes from Deep Time*, so it is fitting to conclude with a comment from the latter work. Speaking of the precedents provided to British scientists by biblical illustrations depicting scenes from deep time, Rudwick suggests:

> The only effective precedents, then, for prehuman scenes with a human viewpoint were those of biblical illustrations of the Creation story. That very fact may help explain the apparent reluctance of 'men of science' to construct analogous scenes, even if they were based on the new evidence of geological science rather than on biblical texts. Conversely, the same fact may explain why that reluctance was first overcome, and science-based scenes first constructed, in the one major European country where—as contemporary observers often noted—the practice of religion was not regarded as antithetical to the practice of science.[52]

Just as geological depictions of deep time were indebted to traditions of biblical illustration, this study of didactic global illustrations suggests that Roger was largely correct when he argued that the historical sciences of the nineteenth century owed something important both to the dynamic tradition of Theories of the Earth and to a culture whose idiom was steeped in the book of Genesis.

[51] For a comparison of didactic illustrations with evidential, ornamental, and technical uses see "Discovery and Demonstration through Nontechnical Diagrams," beginning on page 386. On the frequent juxtaposition of global, regional, and local illustrations see Table 26, "Correspondence of Global and Local illustrations," on page 215ff.

[52] *Scenes from Deep Time*, 229. In the nineteenth century, hexameral idiom was still widely employed by scientists outside Britain, of course. as the examples of Guyot (Swiss) and Dana (American) suggest.

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For convenience, the bibliography is divided into two parts for primary sources and secondary sources. Only works cited are included. Works are sorted by authors and dates. Almost all of the primary sources are contained in the University of Oklahoma History of Science Collections or the Linda Hall Library in Kansas City, Missouri. For references to additional Theories of the Earth and secondary sources about Theories of the Earth see Kerry Magruder, *EarthVisions.net* (*www.earthvisions.net*).

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Appendix: The Creation Week

§ 1. Geneva Bible

The Geneva Bible provides a convenient point of reference for typical non-scholastic hexameral views in Europe and Britain at the beginning of the seventeenth century. Produced by the collaboration of Reformed scholars in the circle of Jean Calvin, the Geneva Bible was published in French, Italian, Spanish and English editions. Over twenty French editions were published in the decades after 1560. The first English edition, produced by a group of scholars including William Whittingham, was published in Geneva in 1560.[1] Two further English editions were printed in Geneva before the first printing in England in 1575. Thereafter over 100 English editions were printed before 1644. In 1579 the Geneva Bible was made the official Bible of Scotland and every head of a household with sufficient means was required to purchase one.[2] More popular in Britain through the seventeenth century than the version authorized by King James,[3] the Geneva Bible was the Bible of the laity, of the Puritan revolution, and thus constituted a measure of general literacy. As the Preface explained, it was designed to make the Bible as it was understood by Reformed scholars clear and intelligible to lay readers, by means of its

> brief annotations upon all the hard places, aswel for the understanding of suche wordes as are obscure.... Forthermore, whereas certeyne places in the bookes of Moses... seemed so darke that by no description thei colde be made easie to the simple reader, we have so set them forthe with figures and notes for the ful declaration thereof, that thei which can not by judgement, being holpen by the annotations noted by the letters a b c. &c. atteyn thereunto, yet by the perspective, and as it were by the eye may sufficiently knowe the true meaning of all suche places. Whereunto also we have added certeyne mappes of Cosmographie which necessarely serve for the perfect understanding and memorie of divers places and countreys....[4]

What the notes of the Geneva Bible reflect was the common currency of Reformed discussion, by definition constituting one traditional, conventional position at the start of the seventeenth century. The text of Genesis 1 with accompanying notes is reproduced from the 1560, 1582, and 1599 editions of the Geneva Bible, which all have the same text as well as illustrations.[5] Unless indicated otherwise, text with notes is from the Geneva Bible; Vulgate text and notes from the Bishops Bible are provided for comparison.

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1 The Geneva Bible was printed in quarto rather than folio size, for convenient reading rather than altar display. It includes 26 woodcuts and five maps. Betteridge describes its innovative features: "We should not underestimate their achievement. It was finely printed in clear roman type, it was modern, it was convenient. It was the first English Bible to be printed with verse divisions (was that so good an idea?). There were maps and illustrations, chapter headings, marginal variant readings abreast of the current Greek and Hebrew scholarship, and exegetical and theological marginal annotations. Such was the concern for accuracy that Hebrew names were transliterated, and where English words and phrases were needed to expand the meaning of the text, they were printed in italics." Maurice S. Betteridge, "The Bitter Notes: The Geneva Bible and its Annotations," *Sixteenth Century Journal* 14 (1983): 42-43. See also Dan G. Danner, "The Later English Calvinists and the Geneva Bible," in *Later Calvinism: International Perspectives*, ed. W. Fred Graham, Sixteenth Century Essays & Studies, no. 22 (Kirksville, Missouri: Thomas Jefferson University Press and Sixteenth Century Journal Publishers, 1994), 489–504. Graham estimates that between 1560 and 1644 more than 140 editions of the Geneva Bible were published.

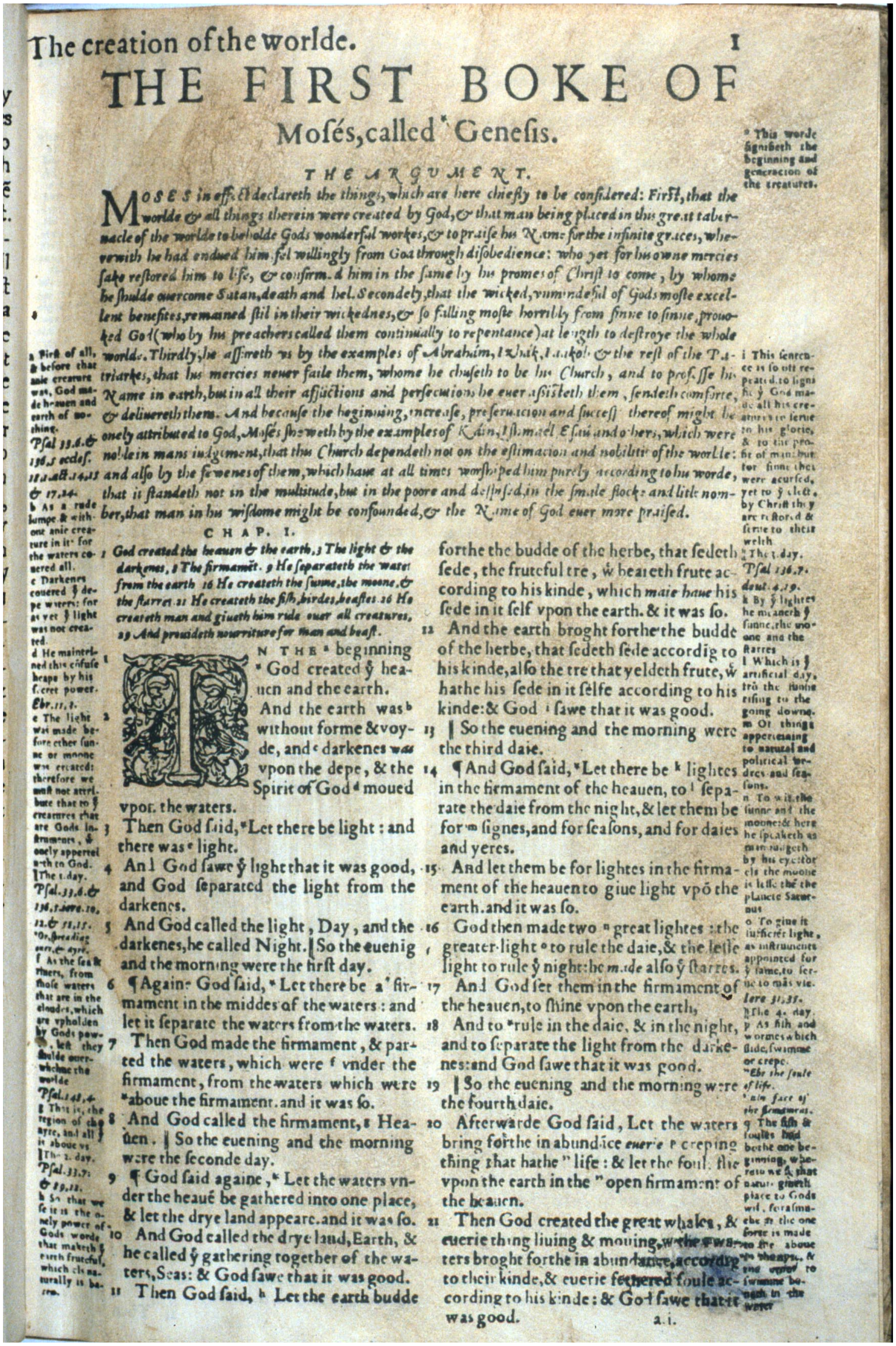
2 Betteridge, 44.

3 The King James version was largely modeled upon it, but dispensed with the controversial annotations.

4 Geneva Bible, "Preface" (1560).

5 This confirms the observation of Betteridge that "Throughout all editions of the Geneva Bible the Old Testament notes did not change." Betteridge, 44.

FIGURE 239. Geneva Bible (1560), English title page,
announcing the "moste profitable annotations vpon all the hard places...." HSCI.



The creation of the worlde. I

THE FIRST BOKE OF
Mosés, called * Genesis.

THE ARGUMENT.

MOSES in effect declareth the things, which are here chiefly to be considered: First, that the worlde & all things therein were created by God, & that man being placed in this great tabernacle of the worlde to beholde Gods wonderful workes, & to praise his Name for the infinite graces, wherewith he had endued him, fel willingly from God through disobedience: who yet for his owne mercies sake restored him to life, & confirmed him in the same by his promes of Christ to come, by whome he shulde overcome Satan, death and hel. Secondely, that the wicked, vnmindeful of Gods moste excellent benefites, remained stil in their wickednes, & so falling moste horribly from sinne to sinne, prouoked God (who by his preachers called them continually to repentance) at length to destroye the whole worlde. Thirdly, he assureth vs by the examples of Abraham, Izhak, Iaakob & the rest of the Patriarkes, that his mercies neuer faile them, whome he chuseth to be his Church, and to professe his Name in earth, but in all their afflictions and persecutions he euer assisteth them, sendeth comforte, & deliuereth them. And because the beginning, increase, preseruacion and successe thereof might be onely attributed to God, Mosés sheweth by the examples of Káin, Ishmael, Esau and others, which were noble in mans iudgement, that this Church dependeth not on the estimacion and nobilitie of the worlde: and also by the fewenes of them, which haue at all times worshiped him purely according to his worde, that it standeth not in the multitude, but in the poore and despised, in the smale flocke and litle nomber, that man in his wisdome might be confounded, & the Name of God euer more praised.

CHAP. I.

1 God created the heauen & the earth, 3 The light & the darkenes, 8 The firmamēt. 9 He separateth the water from the earth 16 He createth the sunne, the moone, & the starres. 21 He createth the fish, birdes, beastes. 26 He createth man and giueth him rule ouer all creatures, 29 And prouideth nourriture for man and beast.

1 IN THE ᵃ beginning * God created ẏ heauen and the earth.
2 And the earth was ᵇ without forme & voyde, and ᶜ darkenes was vpon the depe, & the Spirit of God ᵈ moued vpon the waters.
3 Then God said, * Let there be light: and there was ᵉ light.
4 And God sawe ẏ light that it was good, and God separated the light from the darkenes.
5 And God called the light, Day, and the darkenes, he called Night. ‖ So the euenīg and the morning were the first day.
6 ¶ Againe God said, * Let there be a ᶠ firmament in the middes of the waters: and let it separate the waters from the waters.
7 Then God made the firmament, & parted the waters, which were ᶠ vnder the firmament, from the waters which were * aboue the firmament. and it was so.
8 And God called the firmament, ᵍ Heauen. ‖ So the euening and the morning were the seconde day.
9 ¶ God said againe, * Let the waters vnder the heauē be gathered into one place, & let the drye land appeare. and it was so.
10 And God called the drye land, Earth, & he called ẏ gathering together of the waters, Seas: & God sawe that it was good.
11 Then God said, ʰ Let the earth budde forthe the budde of the herbe, that sedeth sede, the frutefull tre, ẇ beareth frute according to his kinde, which maie haue his sede in it self vpon the earth. & it was so.
12 And the earth broght forthe the budde of the herbe, that sedeth sede accordīg to his kinde, also the tre that yeldeth frute, ẇ hathe his sede in it selfe according to his kinde: & God ⁱ sawe that it was good.
13 ‖ So the euening and the morning were the third daie.
14 ¶ And God said, * Let there be ᵏ lightes in the firmament of the heauen, to ˡ separate the daie from the night, & let them be for ᵐ signes, and for seasons, and for daies and yeres.
15 And let them be for lightes in the firmament of the heauen to giue light vpō the earth. and it was so.
16 God then made two ⁿ great lightes: the greater light ᵒ to rule the daie, & the lesse light to rule ẏ night: he made also ẏ starres.
17 And God set them in the firmament of the heauen, to shine vpon the earth,
18 And to * rule in the daie, & in the night, and to separate the light from the darkenes: and God sawe that it was good.
19 ‖ So the euening and the morning were the fourth daie.
20 Afterwarde God said, Let the waters bring forthe in abundāce euerie ᵖ creping thing that hathe ᵠ life: & let the foule flie vpon the earth in the ʳ open firmament of the heauen.
21 Then God created the great whales, & euerie thing liuing & mouing, which the waters broght forthe in abundance according to their kinde, & euerie fethered foule according to his kinde: & God sawe that it was good.

a.i.

FIGURE 240. Geneva Bible (1560), English, Genesis 1. Note marginal annotations. HSCI.

§ 2. Physica Sacra

Included with each portion of the text of the Geneva Bible are some of the visual representations illustrating the events of the six days (temporally interpreted) from the so-called Copper Bible, Scheuchzer's massive, wonderfully-illustrated *Physica Sacra* (1731).[6] Scheuchzer illustrated the first day with a Copernican cosmic section.

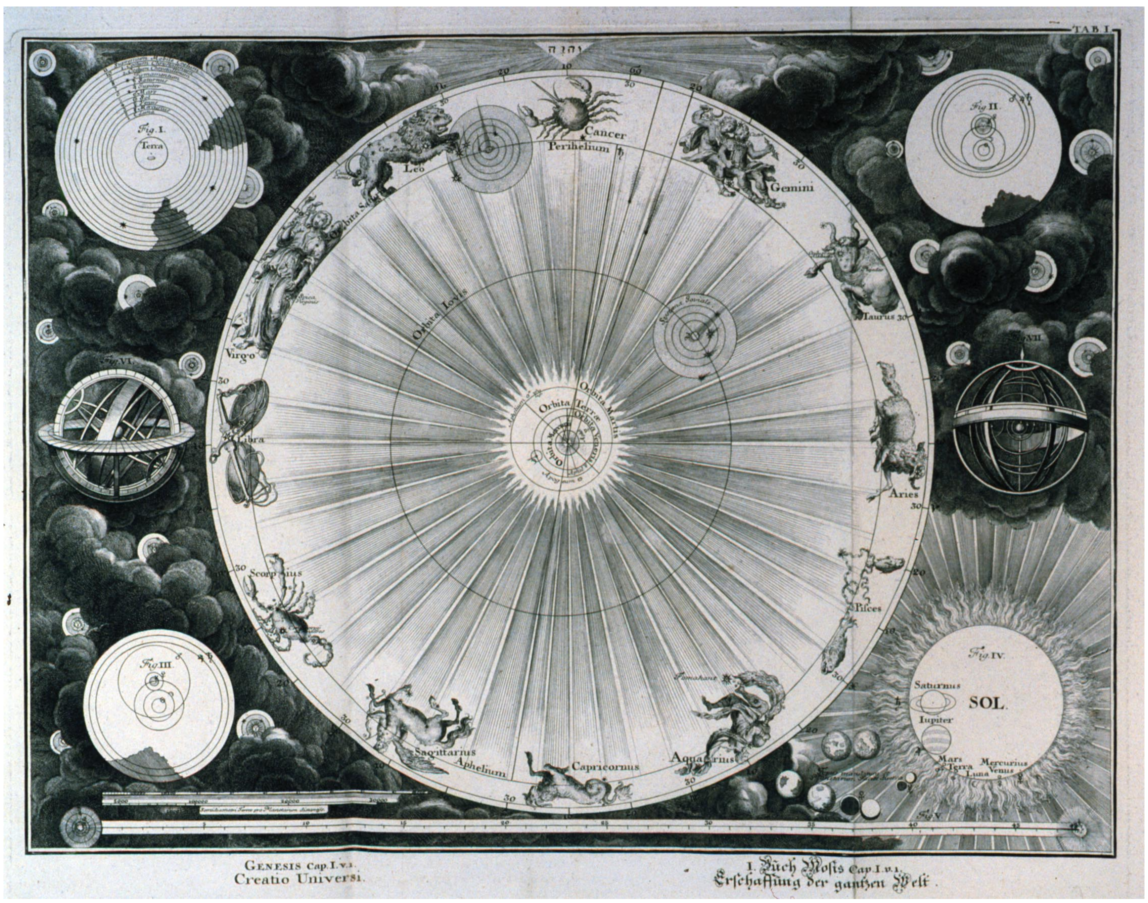


FIGURE 241. J. J. Scheuchzer, *Physica Sacra* (1734), Tab I, "Creatio Universi."

6 Johann Jakob Scheuchzer, *Physica Sacra: Johannis Jacobi Schevchzeri . . . Iconibvs Æneis illustrata procurante & sumtus suppeditante Johanne Andrea Pfeffel, Augustano, Sacræ Cæsareæ Majestatis Chalcographo aulico*, 4 vols. (Avgvstæ Vindelicorvm & Vlmæ [Augsburg & Ulm, Christoph Ulrich Wagner], 1731–1735). This work consists of four volumes of text bound as two folio volumes, and two folio volumes of 760 engraved plates, mostly within ornamental frames, prepared by J.A. Corvinus, G. W. Knorr, J. G. Pintz, C. and H. Sperling, among others. French and German editions were also published; cf. Johann Jakob Scheuchzer, *Physique Sacrée, Ou Histoire Naturelle de la Bible*, 8 vols. (Amsterdam, 1732–1737). The relation of some of the plates to later depictions of prehuman landscapes are discussed in Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1992).

It is beyond the scope of this study to consider the history of biblical interpretation and its bearing on hexameral exegesis, even during the seventeenth century. Some of the secondary sources are cited in "Natural Knowledge and Textual Traditions," beginning on page 66, especially page 73ff. In addition, Edward Grant and William Donahue provide two important studies of the significance of hexameral interpretation for early modern cosmology.[7] Grant hints at the complexity of problems which stimulated scholarly debate on Genesis 1:

> Within these brief passages [for the first four days] commentators were obliged to resolve some basic dilemmas, obscurities, and seeming inconsistencies. How, for example, does the heaven (*caelum*), or firmament, created on the second day, differ from the heaven (*caelum*) created on the first day? How does the light created on the first day compare to the light created on the fourth day? How could plants come forth on the third day if the Sun, whose warmth and light are required, was not created until the fourth day? What are the waters above and below the firmament? Do they differ?[8]

Some of these interpretative questions are raised in the notes to the Geneva Bible or are manifest in the hexameral illustrations of Scheuchzer reproduced here. Moreover, it is instructive to compare Scheuchzer's illustrations with the much earlier sequence from the *Nuremberg Chronicle* (1493) reproduced on page 408ff, and with the nineteenth-century series of Arnold Guyot reproduced in the Epilogue.

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7 William H. Donahue, *The Dissolution of the Heavenly Spheres, 1595–1650* (New York: Arno Press, 1981), and Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200–1687* (Cambridge: Cambridge University Press, 1994).

8 Grant, *Planets, Stars, and Orbs*, 92.

§ 3. In the Beginning...

TABLE 71. "In the beginning"

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:1	In principio creavit Deus caelum et terram.	In the [a]beginning God created ye heauen and the earth.	a. First of all, & before that anie creature was, God made heauen and earth of nothing.” Psalm 33.6 & 136.5. Eccles. 18.1. Acts 14.15 & 17.24.
1:2	Terra autem erat inanis et vacua, et tenebrae super faciem abyssi, et spiritus Dei ferebatur super aquas.	And the earth was [b]without forme & voyde, and [c]darkness was vpon the depe, & the Spirit of God [d]moued vpon the waters.	b. As a rude lumpe & without anie creature in it: for the waters couered all. c. Darkenes couered ye depe waters: for as yet ye light was not created. d. He mainteined this confuse heape by his secret power. Ebr. 11.3.[a]

a. **Bishop’s Bible, 1572**, note on deep: The deepe, the waters, & the heauen, signifie that rude body that was afterward garnished with lightes. The holy Ghost did preserve that confused body.”
Bishop’s Bible, 1595, note on deep: Although the workes of God, both in the creation and in his spiritual operation in man, seee rude and imperfect at the first: yet God by the woorking of his holy spirit, bringeth all thinges to a perfection at the end. The confused heape of heauen and earth was imperfect and darke, and yet not utterly dead, but was endued with the power and strength of God’s spirit, and so made liuely to continue unto the worlds end.”

§ 4. The First Day: Division of Light and Darkness

TABLE 72. Day 1, Physica Sacra

FIGURE 242. Tab II. Darkness covered the face of the deep; note the darkened Earth.

FIGURE 243. Tab III. "Let there be light!"

TABLE 73. Day 1, Text

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:3	Dixitque Deus: "Fiat lux." Et facta est lux.	Then God said, Let there be light: and there was [e]light.	e. The light was made before ether sunne or moone was created: therefore we must not attribute that to ye creatures that are Gods instruments, which onely apperteineth to God.

TABLE 73. **Day 1, Text**

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:4	Et vidit Deus lucem quod esset bona et divisit Deus lucem ac tenebras.	And God sawe ye light that it was good, and God separated the light from the darkenes.	
1:5	Appellavitque Deus lucem Diem et tenebras Noctem. Factumque est vespere et mane, dies unus.	And God called the light, Day, and the darkness, he called Night. So the euening and the morning were // the first day.	// The I. day. Psal. 33.6 & 136.5. Jere. 10.12 & 51.15.

§ 5. The Second Day

On Day 2 God divided the waters above from the waters below, stretching out the sky or firmament between them. The work of the second day required severe hermeneutical gymnastics to square with Aristotelian cosmology, and those interpreters who opted for a non-figurative interpretation (e.g., Basil) often made no attempt to diminish the degree to which they were contradicting the authority of the Philosopher. What are the waters above the firmament? In Beati's cosmic section, they were fluid spheres; for Cartesians, they were vortices; in the Geneva Bible they were simply clouds. For Bellarmine, the idea either that the firmament or the waters above the firmament refers to clouds "is inadmissible because God placed the sun, the moon, and the stars in the firmament and certainly those heavenly bodies are not found in the lower zone of the air."[9]

9 Robert Bellarmine, *The Louvain Lectures (Lectiones Lovanienses) of Bellarmine and the Autograph Copy of his 1616 Declaration to Galileo*, ed. Ugo Baldini and George V., S.J. Coyne, Studi Galileiani, vol. 1, no. 2 (Specola Vaticana: Vatican Observatory Publications, 1984), 12.

TABLE 74. Day 2, Physica Sacra

FIGURE 244. Tab IV. Separation of the waters above the firmament from the waters below.

Caption. The smooth ball of Earth is revealed within the surrounding layers of clouds (E). The center, A, has a smooth surface B, just inside a relatively thin smooth layer with suface C. Light from the Sun, above the clouds, penetrates to illumine surface C. D is the area beyond the clouds, in which resides the bright sun (top center) and the dark moon (lower right corner).

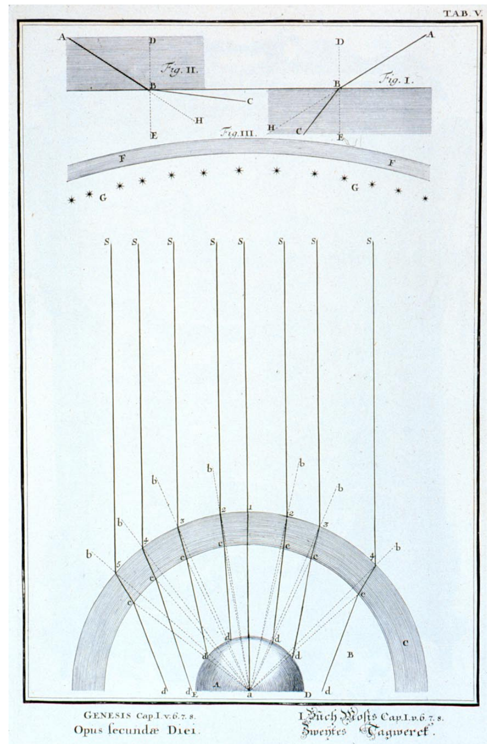


FIGURE 245. Tab V. Refraction of light.

TABLE 75. Day 2, Text

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:6	Dixit quoque Deus: "Fiat firmamentum in medio aquarum et dividat aquas ab aquis."	Againe God said, Let there be a *firmament in the middes of the waters: and let it separate the waters from the waters.	*Or, spreading ouer, & ayre.
1:7	Et fecit Deus firmamentum divisitque aquas, quae erant sub firmamento, ab his, quae erant super firmamentum. Et factum est ita.	Then God made the firmament, & and parted the waters, where were [f]vnder[a] the firmament,[b] from the waters which were aboue[c] the firmament, and it was so.	f. As the sea & riuers, from those waters that are in the cloudes, which are vpholden by Gods power, lest they shulde ouerwhelme the worlde. Psal. 148.4.
1:8	Vocavitque Deus firmamentum Caelum. Et factum est vespere et mane, dies secundus.	And God called the firmament, [g]Heauen. // So the euening and the morning were the seconde day.	g. That is, the region of the ayre, and all that is aboue vs. // The 2. day. Psal. 33.7 & 89.12.

a. Bishop's Bible, 1595, note on under: "As the sea and riuers, from those waters that are in the clouds, which are upholden by Gods power, least they should ouerwhelme the world."

b. Bishop's Bible, 1572, note on firmament: All that roome wherein the ayre, the sunne, moone, and starres be, is so named."

c. Bishop's Bible, 1572, note on above: "It is the power of god, that holdeth up the cloudes. Psalm. 33.b." Bishop's Bible, 1572, note on Psalm 104: 3–6: "It is maruellous that the water, against his nature, should be aboue the aire, and couer the upper part of it, as in manner of a seeling."

§ 6. The Third Day

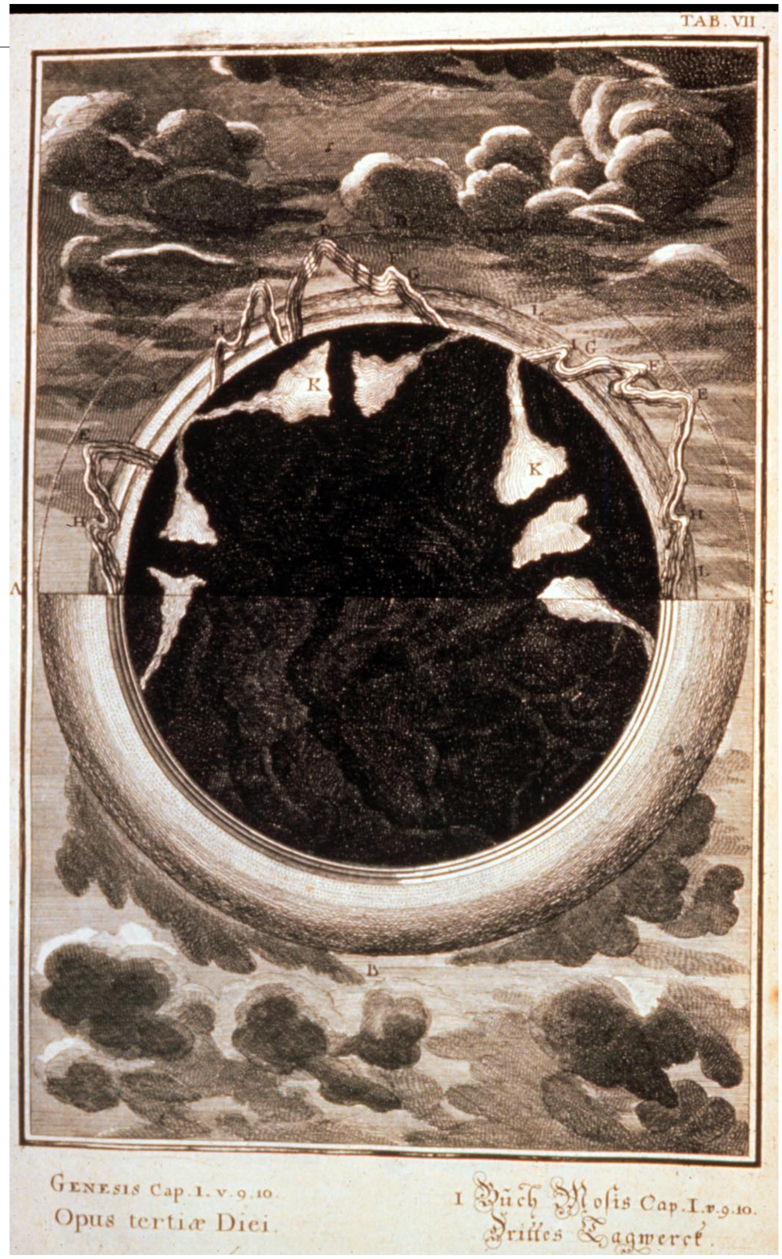


FIGURE 246. Tab VII. Global section showing the Earth at the beginning (lower half) and the end (upper half) of the third day.

Caption. *ABC*: The state of the terraqueous globe before the third day. *ADC*: The state of the same on and after the third day, covered indeed from this time forth with elevations and depressions. *EEE*: The tops of the highest mountains. *FFF*: Summits of smaller mountains. *EG*: Declivities of the Earth from the summits of mountains to the shores of the seas. *LLL*: Seas. *HHH*: Islands. *K*: Subterranean caverns.

At the beginning of the third day, the Earth is covered with water. The smooth watery Earth is surrounded by the waters above, layers of clouds (*E* in Scheuchzer's global section, Figure 246). By the end of the third day, in a manner reconcilable with many Neptunist schemes, the Earth becomes a terraqueous globe, characterized by elevations and depressions, underlain by subterraneous caverns. Scheuchzer surrounded the global section with matching local views: mountains, seas, and other inequalities arose on the third day.

TABLE 76. Day 3, Physica Sacra

FIGURE 247. Tab VI. Landscape scene showing barren, mountainous terraqueous globe.

FIGURE 248. Tab VIII. Second landscape.

FIGURE 249. Tab IX. Covered with vegetation, the habitable globe was completely formed.

TABLE 77. **Day 3, Text**

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:9	Dixit vero Deus: "Congregentur aquae, quae sub caelo sunt, in locum unum, et appareat arida." Factumque est ita.	God said againe, Let the waters vnder the heauen be gathered into one place, & let the drye land appeare, and it was so.[a]	
1:10	Et vocavit Deus aridam Terram congregationesque aquarum appellavit Maria. Et vidit Deus quod esset bonum.	And God called the drye land, Earth, & he called ye gathering together of the waters, Seas: & God sawe that it was good.	
1:11	Et ait Deus: "Germinet terra herbam virentem et herbam facientem semen et lignum pomiferum faciens fructum iuxta genus suum, cuius semen in semetipso sit super terram." Et factum est ita.	Then God said, [h]Let the earth budde forthe the budde of the herbe, that sedeth sede, the fruteful tre, which beareth frute according to his kinde, which maie haue his sede in it self vpon the earth, & it was so.	h. So that we se it is the onely power of Gods worde that maketh ye earth fruteful, which els naturally is baren.
1:12	Et protulit terra herbam virentem et herbam afferentem semen iuxta genus suum lignumque faciens fructum, qui habet in semetipso sementem secundum speciem suam. Et vidit Deus quod esset bonum.	And the earth broght forthe the budde of the herbe, that sedeth sede according to his kinde, also the tre that yeldeth frute, which hathe his sede in it selfe according to his kinde: & God [i]sawe that it was good.	i. This sentence is so oft repeated, to signifie that God made all his creatures to serue to his glorie, & to the profit of man: but for sinne thei were acursed, yet to ye elect, by Christ they are restored & serue to their welth.
1:13	Et factum est vespere et mane, dies tertius.	// So the euening and the morning were the third daie.	// The 3. day. Psal. 136.7, Deut. 4.19.

a. Bishop's Bible, 1572; note: That is, al the waters sohiche were in the topest (tolmest?) parts of the ayre."

§ 7. The Fourth Day

TABLE 78. Day 4, Physica Sacra

FIGURE 250. Tab X. The annual motion of the Sun causes the seasons, marking off the equator and tropics. The Moon determines the length of the month.

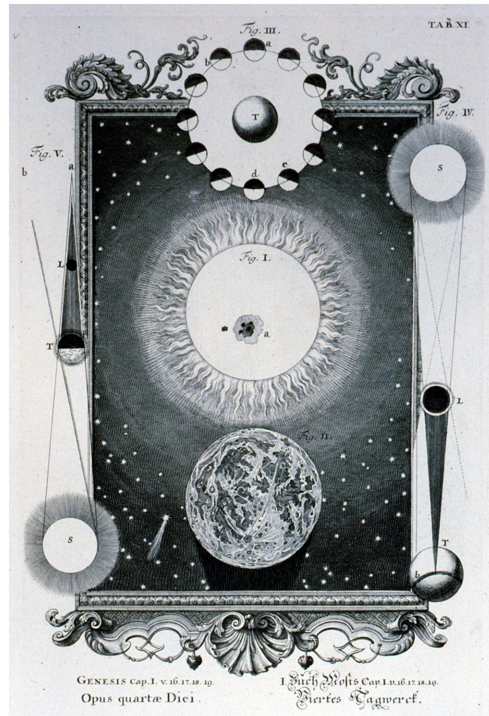


FIGURE 251. Tab XI. God made the Sun (shown with sunspots), the Moon, and stars. Top: Lunar cycle as seen from Earth (T). Left border: Lunar eclipse. Right border: Solar eclipse.

On the fourth day the Sun, Moon, stars and comets appear, filling the places divided on the first day. From the patristic era much discussion had explored the question why they were made at this late date, or whether on this day they just became visible for the first time from the surface of the Earth.

TABLE 79. **Day 4, Text**

Verse	Vulgate	Geneva Bible Text	Notes
1:14	Dixit qutem Deus: “Fiant luminaria in firmamento caeli, ut dividant diem ac noctem et sint in signa et tempora et dies et annos,	And God said, Let there be [k]lightes in the firmament of the heauen, to [l]separate the daie from the night, & let them be for [m]signes, and for seasons, and for daies and yeres.	k. By ye lightes he meaneth ye sunne, the moone and the starres. l. Which is ye artificial day, from the sunne rising to the going downe. m. Of things apperteining to natural and political ordres and seasons.
1:15	ut luceant in firmamento caeli et illuminent terram. Et factum est ita.	And let them be for lightes in the firmament of the heauen to giue light vpon the earth, and it was so.	
1:16	Fecitque Deus duo magna luminaria: luminare maius, ut praeesset diei, et luminare minus, ut praeesset nocti, et stellas.	God then made two [n]great lightes: the greater light [o]to rule the daie, & the lesse light to rule ye night: he made also ye starres.	n. To wit, the sunne and the moone: & here he speaketh as man judgeth by his eye: for els the moone is lesse then the planete Saturnus. o. To giue it sufficient light, as instruments appointed for ye same, to serue to mans vse. Jere. 31.35.
1:17	Et posuit eas Deus in firmamento caeli, ut lucerent super terram	And God set them in the firmament of the heauen, to shine vpon the earth,	
1:18	et praeessent diei ac nocti et dividerent lucem ac tenebras. Et vidit Deus quod esset bonum.	And to rule in the daie, & in the night, and to separate the light from the darkeness: and God sawe that it was good.	
1:19	Et factum est vespere et mane, dies quartus.	// So the euening and the morning were the fourth daie.	// The 4. day.

§ 8. The Fifth Day

On the fifth day ocean life and birds were created, filling the places divided on the second day.

TABLE 80. Day 5, Text

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:20	Dixit etiam Deus: "Pullulent aquae reptile animae viventis, et volatile volet super terram sub firmamento caeli."	Afterwarde God said, Let the waters bring forthe in abundance euerie [p]creping thing that hathe *life: & let the foule flie vpon the earth in the **open firmament of the heauen.	p. As fish and wormes which slide, swimme or crepe. * Ebr. the soule of life. **Ebr. face of the firmament.
1:21	Creavitque Deus cete grandia et omnem animam viventem atque motabilem, quam pullulant aquae secundum species suas, et omne volatile secundum genus suum. Et vidit Deus quod esset bonum;	Then God created the great whales, & euerie thing liuing & mouing, which the [q]waters broght forthe in abundance, according to their kinde, & euerie fethered foule according to his kinde: & God sawe that it was good.	q. The fish & foules had bothe one beginning, wherein we se that nature giueth place to Gods wil, forasmuche as the one sorte is made to flie aboue in the ayre, & the other to swimme beneth in the water.
1:22	benedixitque eis Deus dicens: "Crescite et multiplicamini et replete aquas maris, avesque multiplicentur super terram."	Then God [r]blessed them, saying, Bring forthe frute and multiplie, and fil the waters in the seas, & let the foule multiplie in the earth.	r. That is, by the vertue of his worde he gaue power to his creatures to ingendre.
1:23	Et factum est vespere et mane, dies quintus.	// So the euening & the morning were the fifte day.	// The 5 day.

TABLE 81. Day 5, Physica Sacra

FIGURE 252. Tab XIII. God filled the sky with insects, small flying creatures, and...

FIGURE 253. Tab XIV. ...birds.

FIGURE 254. Tab XV. God filled the oceans with fish and other large creatures...

FIGURE 255. Tab XIX. ...and shellfish.

§ 9. The Sixth Day

On the sixth day land animals and humans were created, filling the dry land which appeared on the third day.

TABLE 82. **Day 7, Text**

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:24	Dixit quoque Deus: “Producat terra animam viventem in genere suo, iumenta et reptilia et bestias terrae secundum species suas.” Factumque est ita.	¶ Moreouer God said, Let the earth bring forthe the *liuing thing according to his kinde, cattel, & that which crepeth, & the beast of the earth, according to his kinde, and it was so.	*Ebr. soule of life. Chap. 5.5 & 9.6. 1 Cor. 11.7. Colos. 3.10.
1:25	Et fecit Deus bestias terrae iuxta species suas et iumenta secundum species suas et omne reptile terrae in genere suo. Et vidit Deus quod esset bonum.	And God made ye beast of the earth according to his kinde, and the cattel according to his kinde, & euerie creping thing of ye earth according to his kinde: & God sawe that it was good.	
1:26	Et ait Deus: “Faciamus hominem ad imaginem et similitudinem nostram; et praesint piscibus maris et volatilibus caeli et bestiis universaeque terrae omnique reptili, quod movetur in terra.”	Furthermore God said, [s]Let vs make man in our [t]image according to our lickenes, and let them rule ouer the fish of the sea, and ouer the foule of the heauen, and ouer the beastes, & ouer all the earth, and ouer euerie thing that crepeth & moueth on the earth.	s. God commanded the water and the earth, to bring forthe other creatures: but of man he saith, Let vs make: signifying that God taketh counsel with his wisdome & vertue, purposing to make an excellent worke aboue all the rest of his creation. t. This image and licknes of God in man is expounded Ephes. 4.24: where it is writen, that man was created after God in righteousnes & true holines, meaning by these two wordes all perfection, as wisdome, trueth, innocencie, power, &c. Wisdo. 2.23. Eccles. 17.1. Matt. 19.4.
1:27	Et creavit Deus hominem ad imaginem suam; ad imaginem Dei creavit illum; masculum et feminam creavit eos.	Thus God created the man in his image: in the image of God created he him: he created them male and female.	

TABLE 82. **Day 7, Text**

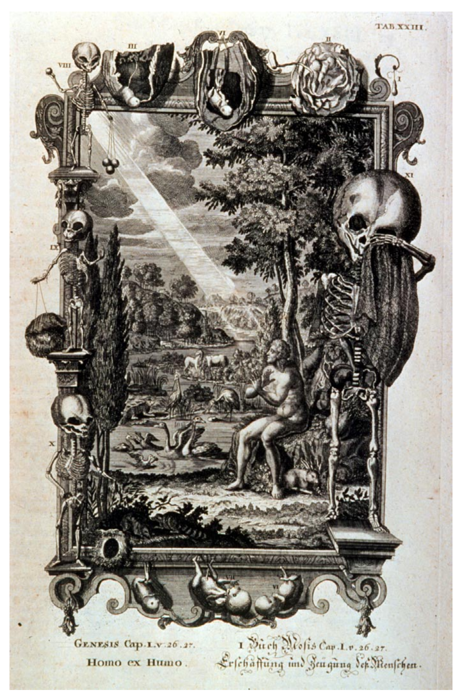
Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
1:28	Benedixitque illis Deus et ait illis Deus: “Crescite et multiplicamini et replete terram et subicite eam et dominamini piscibus maris et volatilibus caeli et universis animantibus, quae moventur super terram.”	And God [u]blessed them, and God said to them, Bring forthe frute and multiplie, and fil the earth, and subdue it, and rule ouer the fish of the sea and ouer the foule of the heauen, & ouer euerie beast that moueth vpon the earth.	u. The propagacion of man is the blessing of God, Psal. 128. Chap. 8.17 & 9.1.
1:29	Dixitque Deus: “Ecce dedi vobis omnem herbam afferentem semen super terram et universa ligna, quae habent in semetipsis fructum ligni portantem sementem, ut sint vobis in escam	And God said, Beholde, I haue giuen vnto you [x]euerie herbe bearing sede, which is vpon all the earth, & euerie tre, wherein is the frute of a tre bearing sede: that shalbe to you for meat.	x. Gods great liberalitie to man taketh away all excuse of his ingratitude. Chap. 9.3. Exod. 3.17. Eccles. 39.21. Mar. 7.37.
1:30	et cunctis animantibus terrae omnique volucri caeli et universis, quae moventur in terra et in quibus est anima vivens, omnem herbam virentem ad vescendum.” Et factum est ita.	Likewise to euerie beast of the earth, and to euerie foule of the heauen, & to euerie thing that moueth vpon the earth, which hathe life in it selfe, euerie grene herbe shalbe for meat, and it was so.	
1:31	Viditque Deus cuncta, quae fecit, et ecce erant valde bona. Et factum est vespere et mane, dies sextus.	And God sawe all that he had made, & lo, it was very good. So the euening and the morning were the sixt day.	

TABLE 83. Day 6, Physica Sacra

FIGURE 256. Tab XXI. God filled the land…

FIGURE 257. Tab XXII. …with animals.

FIGURE 258. Tab XXIII. God created Adam from the dust of the ground, "Homo ex Humo."



§ 10. The Seventh Day

TABLE 84. **Day 7, Text**

Verse	Vulgate	Geneva Bible Text	Geneva Bible Notes
2:1	Igitur perfecti sunt caeli et terra et omnis exercitus eorum.	Thus the heauens and the earth were finished, & all the [a]hoste of them.	a. That is, the innumerable abundance of creatures in heauen & earth. Exod. 20.11 & 31.17. Ebr. 4.4.
2:2	Complevitque Deus die septimo opus suum, quod fecerat, et requievit die septimo ab universo opere, quod patrarat.	For in the seuenth day God ended his worke which he had made, & the seuenth day he [b]rested from all his worke, which he had made.	b. For he had now finished his creacion, but his prouidence stil watcheth ouer his creatures, and gouerneth them.
2:3	Et benedixit Deus diei septimo et sanctificavit illum, quia in ipso requieverat ab omni opere suo, quod creavit Deus, ut faceret.	So God blessed the seuenth day, & [c]sanctified it, because that in it he had rested from all his worke, which God had created and made.	c. Appointed it to be kept holy, that man might therein consider ye excellencie of his workes & Gods goodnes towards him.
2:4	Istae sunt generationes caeli et terra quando creata sunt.	These are the *generations of the heauens & of the earth, when thei were created, in the day that the Lord God made the earth and the heauens,	*Or, the original & beginning.