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THE STUDY OF FOSSILS IN THE LAST HALF

OF THE SEVENTEENTH CENTURY

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This dissertation
is lovingly dedicated to
my wife, Graciela, and to
my son, Howard Kenneth, Jr.

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INTRODUCTION

The purpose of this work is to analyze and to interpret some early theoretical efforts that attempted to explain the origin and development of fossils, and their later application to the study of the history of the earth. These theoretical endeavors laid the groundwork for later successes, successes that eventually led to the creation of the science of palaeontology. The use of the term "fossil" in this text is complicated by the change in meaning of its definition from the seventeenth century until modern times. Originally, a fossil was any body, such as a mineral, a rock, or other object, that was removed from the earth by digging. In addition, the word "fossil" referred to any body found buried in the earth. This meaning was derived from the Latin *fossilis*, or "dug up" which was taken from *fodere*, or "to dig."[1] Fossil, usually denoted by the Latin

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[1] Sir James Augustus Henry Murray *et al*. (eds.), *The Oxford English Dictionary; Being a Corrected Re-Issue with an Introduction, Supplement, and Bibliography of a New English Dictionary on Historical Principles, Founded Mainly on the Materials Collected by the Philological Society* (13 vols.; Oxford: At the Clarendon Press [1961]), pp. 485-486.

fossilium, was used in this sense from Pliny's day to early modern times.[2] Therefore, fossil could be used in reference to fossil coal, or fossil salt, or, in the Philosophical Transactions in 1665, as "Of Some Fossils as Sand, Gravels, Earths."[3] There were fossil fish as well, supposed from ancient times to have lived underground.[4] Finally, fossils also were things that partook of the nature of fossils, which were contained, petrified or unpetrified,

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[2]Ethan Allen Andrews, Harper's Latin Dictionary: A New Latin Dictionary, Founded on the Translation of Freund's Latin-German Lexicon, Edited by E. A. Andrews, Ll.D. (Revised, enlarged, and in great part rewritten by Charlton T. Lewis and Charles Short; New York: American Book Company, 1907), p. 774.

[3][Anon.], "Of the Mundus Subterraneus of Athanasius Kircher," Philosophical Transactions: Giving Some Accompt of the Present Undertakings, Studies and Labours of the Ingenious in Many Considerable Parts of the World, I, No. 6 (November 6, 1665), p. 111. Cited hereafter as Philosophical Transactions.

[4]Robert Lovell, ΠΑΝΖΩΟΡΥΚΤΟΛΟΓΙΑ, Sive Panzoologicomineralogia. Or a Compleat History of Animals and Minerals, Containing the Summe of all Authors, both Ancient and Modern, Galenicall and Chymicall, Touching Animals, viz. Beasts, Birds, Fishes, Serpents, Insects, and Man, As to their Place, Meat, Name, Temperature, Vertues, Use in Meat and Medicine, Description, Kinds, Generation, Sympathie, Antipathie, Diseases, Cures, Hurts, and Remedies & etc. With the Anatomy of Man, His Diseases, with Their Definitions, Causes, Signes, Cures, Remedies: And Use of the London Dispensatory, With the Doses and Forms of All Kinds of Remedies: As also a History of Minerals, viz. Earths, Metalls, Semimetalls, their Naturall and Artificiall Excrements, Salts, Sulphurs, and Stones, With their Place, Matter, Names, Kinds, Temperature, Vertues, Use, Choice, Dose, Danger, and Antidotes. Also An Introduction to Zoography and Mineralogy; Index of Latine Names, with their English Names; Universall Index of the Use and Vertues (Oxford: Printed by Henr Hall, for Jos. Godwin. 1661), pp. [xix - xx].

in rocks. Such were fossil resins, plants, and shells.[5]

At no time during this period did the word "fossil" come to assume its modern, narrower meaning, which is as the remains--whether an impression, trace, or actual fabric--of plants and animals from some previous age, which are embedded in the earth's crust.[6] Useful definitions were, however, presented in the Lexicon Technicum, published in 1704.[7] Fossils were still denoted as "All Bodies whatever that are dug out of the Earth, . . .," but these bodies were divided into two classes. First were those which were natives of the earth. Second were those which were adventitious. Under the second group were placed the exuvial or remnants of sea and land animals, such as fossil shells, bones, and teeth. Adventitious fossils were also called "foreign" or "extraneous" fossils.[8] Another important entry in the Lexicon Technicum concerning fossils was that of "formed or figured stones," or rocks that were

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[5]Noah Webster, Webster's New International Dictionary of the English Language (2d ed., unabridged; Springfield, Massachusetts: G. & C. Merriam Company, 1959), p. 996.

[6]Ibid.

[7]John Harris, Lexicon technicum, or an Universal English Dictionary of Arts and Sciences, Explaining Not Only the Terms of Art, but the Arts Themselves (London: Printed for Dan Brown, Tim Goodwin, John Walthoe, Tho. Newborough, John Nicholson, Tho. Benskin, Benj. Tooke, Dan. Midwinter, Tho. Leigh, and Francis Coggan, 1704). Harris' book presented a fair representation of contemporary definitions of fossils, even though he exhibited a bias for the works of John Woodward (1665-1736).

[8]Ibid., "Fossils."

so made that they bore a close resemblance to the "external Figure and Shape of Muscles, Cockles, Periwinkles, and other shells."[9] Both of these entries reveal the broadness of the usage of the word fossil, as compared with its present sense.

Since this dissertation is concerned with fossils in terms of their modern context, "native fossils" will seldom be discussed. All the other variants of fossil noted in the Lexicon Technicum, though, will be discussed. "Adventitious, extraneous, or foreign" fossils will have approximately the same meaning as the modern definition of fossils, that is, as remains or traces of organic bodies found within the earth. "Figured," or "formed stones," will be utilized in their contemporary sense, as bodies made of stony substances that resemble shells, plants, or animals. "Adventitious fossils" and "native fossils" will be used when necessary, in order to avoid confusing the old and new use of "fossil." The word "fossil" itself will be employed in a modern sense, except when it occurs within the context of quotations from contemporary sources, in which instance it will have its earlier general significance.

Unfortunately, far too little attention is devoted to this early work in the histories of geology. In these

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[9] Ibid., "Formed Stones."

histories, short discussions on fossils are usually presented about relatively well-known figures such as Robert Hooke (1635-1703), Nicolaus Steno (1638-1686), or Martin Lister (1638-1712), while men such as Paolo Boccone (1633-1704) and Agostino Scilla (1639-1700) are virtually, if not wholly, ignored. Charles Lyell in the first volume of his *Principles of Geology* (1830), devotes about the first one hundred pages to a summary of the history of geology, fourteen of which are concerned with the seventeenth century.[10] William Whewell in volume three of his *History of the Inductive Sciences From the Earliest to the Present Times* (1837) dismisses the early study and collection of fossils in one section of five pages.[11] Karl Alfred von Zittel discusses only in brief various opinions about fossils in the introduction, although the paragraphs on Hooke are good.[12] The English translation of this book appeared in 1901.[13] Archibald Geikie addresses himself to

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[10] Sir Charles Lyell, *Principles of Geology, Being An Attempt to Explain the Former Changes of the Earth's Surface, By Reference to Causes Now in Operation* (3 vols.; London: John Murray, 1830-1833).

[11] William Whewell, *History of the Inductive Sciences, From the Earliest to the Present Times* (3 vols.; London: John W. Parker, 1837).

[12] Karl Alfred von Zittel, *Geschichte der Geologie und Paläontologie bis ende des 19 Jahrhunderts* ("Geschichte der Wissenschaften in Deutschland, Neuere Zeit," Bd. 23; München und Leipzig: Druck und Verlag von R. Oldenbourg, 1899).

[13] Karl Alfred von Zittel, *History of Geology and Palaeontology to the End of the Nineteenth Century*,

the struggle between theology and geology in this period. Dwelling upon a few of the larger figures, Geikie underrates the influence of their accomplishments.[14] Horace B. Woodward's little book, History of Geology (1911), has a small section entitled "Science in the Seventeenth Century," which entirely concerns geology. It is broad in scope, and far too limited in detail by its eight-page length.[15] Frank Dawson Adams' The Birth and Development of the Geological Sciences (1938; reprinted, 1954) is considered a standard work on the history of geology to early modern times. His treatment of formed stones and the foundation of paleontology, however, glosses over the seventeenth century in favor of the eighteenth.[16] Short sketches in the book are of interest to the study of fossils, such as that on Nicolaus Steno and Paolo Boccone in the chapter on the generation of stones, but the general effect is lack of depth.[17] Later works do not surpass that of Adams' in stature. Carroll Lane Fenton and Mildred Adams Fenton's

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trans. Maria M. Ogilvie-Gordon ("The Contemporary Science Series"; London: Walter Scott, 1901).

[14]Archibald Geikie, The Founders of Geology (2d ed.; London: Macmillan and Co., Limited, 1905).

[15]Horace B. Woodward, History of Geology ("A History of the Sciences"; New York: G. P. Putnams Sons, 1911), pp. 10-18.

[16]Frank Dawson Adams, The Birth and Development of the Geological Sciences (Baltimore: The Williams and Wilkins Company, 1938).

[17]Ibid., pp. 115-116.

book is designed for a popular audience.[18] Carl Christoph Beringer gives Leibniz a good review, mentions Steno and Hooke, and otherwise ignores the study of fossils in the seventeenth century.[19] Francis C. Haber in The Age of the World, Moses to Darwin (1959) and in "Fossils and Early Cosmology," which is chapter one in Forerunners of Darwin, 1745-1859 (1959), gives his discussion of early theories about fossils an important place within his framework. This discussion, however, does not occupy the central position, and is devoted to the ideas of more important men, such as Hooke, Steno, and John Ray (1627-1705).[20] Helmut Hölder, in his first chapter called "From Myth to Theory," moves too rapidly from Pliny the Elder (23-79) to the eighteenth century. Of early theorists, he treats at length only with Steno.[21] Andre Cailleux discusses the seventeenth century too broadly and concisely to merit comment.[22]

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[18] Carroll Lane Fenton and Mildred Adams Fenton, Giants of Geology (Garden City, New York: Doubleday and Company, Inc., 1956).

[19] Carl Christoph Beringer, Geschichte der Geologie und des geologischen Weltbildes. (Stuttgart, F. Enke, 1954).

[20] Francis C. Haber, The Age of the World, Moses to Darwin (Baltimore: The Johns Hopkins Press, 1959). See also Bentley Glass, Oswei Temkin and William L. Straus, Jr. (eds.), Forerunners of Darwin, 1745-1859 (Baltimore: The Johns Hopkins Press, 1959).

[21] Helmut Holder, Geologie und Paläontologie. In Texten und ihrer Geschichte (Freiburg: Verlag Karl Alber, 1960).

[22] André Cailleux, Histoire de la Geologie ("Que Sais-Je?, Le Point des Connaissances Actuelles, N° 962," Paris: Presses Universitaires de France, 1961).

None of these books cover competently the subject of the early study of fossils. All betray a want of profundity in this area.

CHAPTER I

AN HISTORICAL INTRODUCTION TO THE STUDY OF FOSSILS

At a very early period even the most casual observers of the earth's crust noted that rocks found in the earth's strata often possessed certain marks or forms that resembled living creatures or plants. Sometimes designs on those rocks would represent other objects as well, such as heavenly bodies or buildings. One of the first writers to study these impressions was Xenophanes of Colophon (fl. 540-510 B.C.). Xenophanes believed that everything was earth and water, and that all things had once been mixtures of the two elements. This mixture was mud. Moisture dissolved this mud, but objects originally produced in the mud were left behind. Examples of these objects were the shells found in the hills, imprints of a fish and of seaweed in the Syracusan quarries, and flat impressions of all types of marine creatures on Malta. Xenophanes probably believed in a cyclical philosophy, for destruction and rebirth occurred with each mixture and separation of earth and water.[1]

Xanthus of Lydia (fl. 480 B.C.?) noted that during a great drought in the reign of Artaxerxes every river, lake, and well over a wide area became dry. In many of these regions, which were far from the sea, he observed sea fossil shells, some of them cockles, and some scallop shells. These observations, coupled with the phenomena of salt lakes in Armenia, Matiana, and Lower Phrygia, led him to believe that the sea had once covered this region.[2] Herodotus of Halicarnassus (c. 484-c. 425 B.C.) thought that the petrified sea-shells that he had seen in the hills of lower Egypt indicated that the sea had once covered this land.[3] Eudoxus of Cnidus (c. 408-c. 355 B.C.) saw

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[1]John Burnet, Early Greek Philosophy (4th ed.; London: Adam & Charles Black, 1945), pp. 123-24; George Sarton, Introduction to the History of Science ("Carnegie Institute of Washington Publication," No. 376, 3 vols.; Washington, D.C.: Carnegie Institution of Washington, 1927-1948), I, 73; Francis C. Haber, The Age of the World, Moses to Darwin (Baltimore: The Johns Hopkins Press, 1959), p. 38; and Frank Dawson Adams, The Birth and Development of the Geological Sciences (Baltimore: The Williams & Wilkins Company, 1938), p. 10.

[2]Strabo, The Geography of Strabo, trans. with notes, H. C. Hamilton and W. Falconer ("Bohn's Classical Library," vols. 74-76, 3 vols.; London: Henry G. Bohn, 1854-1857), I, Bk. 1, Ch. 3, par. 4, 78; Adams, pp. 11-14; and George Sarton, A History of Science: Hellenistic Science and Culture In the Last Three Centuries B.C; (Cambridge, Massachusetts: Harvard University Press, 1959), p. 422.

[3]Herodotus, History, trans. A. Godley (4 vols.; New York: G. P. Putnam's Sons, 1920-1938), I, Bk. II, Ch. 12, p. 288; Sarton, Introduction, I, 105; Haber, p. 38; and Adams, pp. 11-17.

fossil fish in the Paphlagonian rocks.[4] Eratosthenes (c. 273-c. 192 B.C.) mentioned that it was quite interesting to find large numbers of oyster, mussel, and scallop shells, and salt-water lakes two or three thousand stadia inland from the sea. He witnessed near a temple of Ammon and along a road running beside it, for a distance of some 3,000 stadia, many oyster shells, salt-beds, and salt-springs. Eratosthenes believed, as did Xanthus, that the sea was once where there was now land.[5]

Another believer that the sea once covered what was now dry land was Aristotle of Stagira (384-322 B.C.). To Aristotle, however, the replacement of sea by land was a reversible and continually recurring cycle. This process occurred gradually in a regular manner throughout successive time intervals, intervals which were so extensive in comparison to a human temporal scope, as to be unnoticeable to living mankind. Egypt, Mycenae, and Argos, for example, had undergone small but perceptible changes within historical ages, which were part of a cyclical pattern. Again and again, springs ceased to water a land, which then became dry and caused the populace to leave. Erosion ensued, creating sediment which blocked river channels, forming lakes, bogs, and fertile land. The seas ebbed

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[4]Sarton, Introduction, I, 117; and Adams, p. 12.

[5]Strabo, I, 77-78; Haber, pp. 38-39; Adams, p. 12; and Sarton, Introduction, I, 174.

and flowed, once baring, then inundating, the earth.[6]

The principal agency of these changes was the sun, which by its course increased or diminished the heat and cold within various regions inside the earth. Different parts of the earth, therefore, assumed different characters. Some were moist for a while, then dried and aged. The springs and rivers failed next, and effected the recession of the sea near them. Concurrently, other areas were enriched with moisture and life.[7]

Moreover, these activities were not subject to catastrophes, save in a small, intensified local phenomenon, such as the Deucalion Flood.[8] Thus, the Aristotelian cosmogony was both dynamic and uniformitarian, and was to exercise a great deal of influence upon medieval and early modern geology. It was, in addition, bound by an eternal universe and an eternal time, both of which concepts were later to be repugnant to Christianity.[9] As Aristotle said:

> So it is clear since there will be no end to time and the world is eternal, that neither the Tanais

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[6]Aristotle, Meteorologica, Vol. III: The Works of Aristotle Translated into English, ed. J. A. Smith and W. D. Ross (12 vols.; Oxford: At the Clarendon Press, 1908-52), Bk. I, Ch. 14, 351^a, 351^b, 352^a, 14-36, 1-16.

[7]Ibid.

[8]Ibid., 352^a, 14-36.

[9]John C. Greene, The Death of Adam: Evolution and Its Impact on Western Thought (Ames, Iowa: The Iowa State University Press, 1959), p. 8. See also Haber, p. 40.

> nor the Nile has always been flowing, but that the region whence they flow was once dry: for their effect may be fulfilled, but time cannot. And this will be equally true of all other rivers. But if rivers come into existence and perish and the same parts of the earth were not always moist, the sea must needs change accordingly. And if the sea is always advancing in one place and receding in another it is clear that the same parts of the whole earth are not always either sea or land, but that all this changes in the course of time.[10]

This concept was not to go unchallenged. As was true with many other philosophical dualisms, a fundamental contrast between opposing views of geological processes was established by the Greeks. These positions became known much later as uniformitarianism and catastrophism, and it was against the latter that Aristotle wrote.[11]

One particular group of these catastrophists was called creationists. The creationists believed in a beginning and in an end, together with the concept of an absolute time. They felt that the world was now in a process of decay, because the sea level was falling, as one could have noted by observing the marine fossils on mountains. Eventually, fire would finish the earth. Some of these catastrophic creationists compromised with the uniformitarians, believing in cycles of creation and destruction. They became what might be described as

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[10] Aristotle, Meterologica, Bk. I, Ch. 14, 353^a, 15-24.

[11] Ibid., 353^b, 34-36, 1-4.

catastrophic uniformitarians.[12]

The struggle with the creationists by Aristotle was marked by his slight need for fossil evidence for geological changes. The principal reason for this was the interference of certain agencies within his eternal but ceaselessly changing cosmogony. Besides the effects of the winds, earthquakes, thunderbolts, and other forces, there was a direct influence exercised upon the earth by the sun and other celestial bodies.[13] It was possible for fossils to be produced by these latter agencies.[14] In particular, the heat emitted by the sun or other heavenly bodies would enter the earth. At places where the heat would encounter favorable circumstances, it would generate exhalations. These exhalations made possible a new arrangement of the elements, and created fossils and metals.[15] As Aristotle observed:

> Just as its twofold nature of the sun's heat gives rise to various effects in the upper region, so here it causes two varieties of bodies. We maintain that there are two exhalations, one vaporous the other smoky, and there correspond two kinds of bodies that originate in the earth, 'fossiles' and metals. The heat of the dry exhalation is the cause of all 'fossiles.'

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[12] Pierre Duhem, Études sur Léonard de Vinci, ceux qu'il a lus et ceux qui l'ont lu (Seconde série; Paris: F. De Noble, 1955), 288-89.

[13] Adams, p. 12; and Haber, p. 41.

[14] Aristotle, Meterologica, Bk. III, Ch. 6, 378a, 378b, 16-36, 1-4; Haber, p. 41; and Adams, pp. 78-81.

[15] Ibid.

> Such are the kinds of stone that cannot be melted, and realgar, and ochre, and muddle, and sulphur, and the other things of that kind, most 'fossiles' being either coloured lye or, like cinnabar, a stone compounded of it. The vaporous exhalation is the cause of all metals, those bodies which are either fusible or malleable such as iron, copper, gold. All these originate from the imprisonment of the vaporous exhalation in the earth, and especially in stones. Their dryness compresses it, and it congeals just as dew or hoar-frost does when it has been separated off, though in the present case the metals are generated before that segregation occurs. Hence, they are water in a sense, and in a sense not. Their matter was that which might have become water, but it cannot no longer do so: nor are they, like savours due to a qualitative change in actual water. Copper and gold are not formed like that, but in every case, the evaporation congealed before water was formed. Hence, they all (except gold) are affected by fire, and they possess an admixture of earth; for they still contain the dry exhalation.[16]

Aristotle distinguished between fossils and metals, but fossils meant to him, as they did to others until modern times, anything dug from the earth. He did not proceed to differentiate organic remains from minerals. Probably Aristotle, who had made numerous personal observations in natural history, was aware of fossil remains.[17] However, he only referred to them once in his works, in a passage in which he noted that large numbers of fish lived motionless within the earth and were found by digging.[18]

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[16]Aristotle, Meterologica, Bk. III, Ch. 6, 378[a], 378[b], 16-36, 1-4.

[17]Marshall Clagett, Greek Science in Antiquity (New York: Abelard-Schuman, Inc., 1955), pp. 63-66.

[18]Aristotle, "De Respiratione," Meteorologica, Vol. III: The Works of Aristotle Translated into English, ed. J. A. Smith and W. D. Ross (12 vols.; Oxford: At the Clarendon Press), Ch. 15, 475[b].

Apparently he thought that those discovered fish had once been alive underground, then had died and fossilized.

The study of fossils continued after Aristotle throughout classical antiquity. Theophrastus of Eresos (c. 372-c. 287), a student of Aristotle and his successor as head of the Lyceum, wrote of fossils found in rocks near the Pontic city of Heraclea, and in Paphlagonia, in his work On Fishes.[19] Theophrastus also discussed pieces of fossil ivory, of which he believed that they, together with other bone-like stones, were spontaneously generated within the earth.[20] He speculated, though, that underground fossil fish might have arisen from eggs deposited by parent fish swimming through subterranean water connections between seas.[21] Petrified Indian reeds, and possibly fossil resins as well, came to his attention.[22]

Strabo (c. 63 B.C.-20 A.D.) believed that the mountains were raised from beneath the seas by central fires which caused earthquakes. This was the reason why

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[19] Sarton, Introduction, I, 143-44; Adams, p. 12; and George Sarton, A History of Science: Ancient Science Through the Golden Age of Greece (Cambridge, Massachusetts: Harvard Press, 1953), pp. 559-60.

[20] Earle R. Caley and John F. C. Richards, Theophrastus on Stones: Introduction, Greek Text, English Translation, and Commentary (Columbus, Ohio: The Ohio State University, 1956), pp. 53, 135-36.

[21] Haber, p. 42; and Adams, p. 13.

[22] Caley and Richards, Theophrastus, pp. 53, 112-13, 142.

one could find sea shells at great elevations.[23]

In the first century after Christ, Pliny the Elder (23 A.D.-79 A.D.), in his Natural History, mentioned fossil ivory. He quoted Theophrastus's statements that stones gave birth to other stones and that stones resembling bones have been excavated from the earth.[24] Pliny also wrote about petrifying exhalations within shafts which were dug in Spain to procure a certain stone. Animals sometimes fell into these openings, and within a year their bones would resemble the same stones. Probably this theory of exhalations stemmed from Aristotle.[25]

The Emperor Caesar Augustus (27 B.C.-14 A.D.) collected fossil bones at his villa upon the Isle of Capri. According to Caius Suetonius Tranquillus (72 A.D.-123 A.D.), some thought these limbs to be those of wild beasts and sea monsters, while others took them for the bones of giants.[26]

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[23] Strabo, I, Bk. I, Ch. 3, 1-22, 74-97; Sarton, Introduction, I, 227-29; and Adams, p. 26.

[24] Kenneth C. Bailey (ed., trans.), The Elder Pliny's Chapters of Chemical Subjects (2 pts.; London: Edward Arnold & Co., 1932), pt. II, 253-54; and Plinius Secundus, Pliny: Natural History. With an English Translation, trans. H. Rackham, W. H. D. Jones, and D. E. Eichholz ("The Loeb Classical Library"; Cambridge, Massachusetts: Harvard University Press, 1938-1963), X, Bk. 36, 108-109, 134. See also "Introduction," x-xv; Caley and Richards, p. 136; and Sarton, A History, p. 561.

[25] Plinius Secundus, IX, Bk. 36, X-XV, 128-129, 163.

[26] Caius Suetonius Tranquillus, Suetonius' Lives of the Twelve Caesars, trans. and introd. H. M. Bird (Chicago: Argus Books, 1934), p. 110.

The Arabs pursued the Greco-Roman interest in fossils. Avicenna, or Ibn-Sina (980-1037), returned to the idea of the organic origin of fossils. He believed that both animal and vegetable bodies could be petrified, either by a petrific force found in places where stone was in abundance, or else by the drying of the mud which enveloped them.[27] He supported this opinion by noting that:

> In Arabia there is a tract of volcanic earth which turns to its own colour everyone who lives there and every object which falls upon it. I myself have seen a loaf of bread in the shape of a round, flat cake--baked, thin in the middle, and showing the marks of teeth--which had petrified but still retained its original colour, and on one of its sides was the impression of the lines in the oven. I found it thrown away on a mountain near Jajarm, a town of Khwiasan, and I carried it about with me for a time. These things appear strange only on account of their infrequent occurrence; their natural causes, however, are manifest and well-known.[28]

Avicenna also reasoned that fossils were good evidence that some mountains had risen from the ocean floor, although he believed that subterranean gases were more important in mountain building than was sedimentation from water. The newly raised earth was transformed into rock by the action of the sun on the clay, or "conglutination," and by the solidification or "congelation" of the water particles, or else by an unknown congealing petrifying virtue. The

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[27] G. M. Wickens (ed.), Avicenna: Scientist and Philosopher, A Millenary Symposium (London: Luzac & Company, Ltd., 1952), p. 98; Duhem, pp. 302-319; Adams, pp. 18, 82-83, 335; and Haber, p. 43.

[28] Wickens, p. 98.

yellowish soil found on the mountains was the product of the decay of organic remains which had been transported there by water.[29] Finally, Avicenna remarked that the mountains contained rocks which, if broken open, would be found to hold parts of various marine animals, such as sea shells.[30]

Avicenna seemingly reflected the views of Aristotle on fossils, for probably both his theory of a petrifying power or vis lapidificativa in nature, as well as his thoughts on geological processes, were derived from Aristotle. His treatise on geological changes, De mineralibus, was attached to his translation of Aristotle's Meteorologica.[31]

Western writers on fossils were Vincent of Beauvais (c. 1200-c. 1264) and Albert Magnus (c. 1193-1280). Vincent compiled a large encyclopedia, the Speculum Mundi, sometime between 1240 and 1264. He attempted to condense all knowledge into this work. Vincent used many sources, including Aristotle and Pliny. He was not original.[32]

Albertus wrote a commentary on the De Mineralibus

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[29]Wickens, p. 97; Adams, p. 82; and Geikie, p. 43.

[30]Wickens, p. 97.

[31]Duhem, 302-319; Haber, p. 43; and Adams, p. 18.

[32]Sarton, Introduction, II, pt. 2, 929-30; II, pt. 1, p. 49; and Haber, p. 43.

of Avicenna.[33] Albertus emphasized the action of gases and minimized the role of temporary deluges in mountain building. He did, though, find deluges necessary to explain the presence of fossil shells in rocks.[34] Albertus also formulated a theory of fossil formation that showed strong Avicennan-Aristotelian influences.[35] He believed, as had Avicenna, that a formative virtue within the earth was constantly trying to produce organic forms from inorganic forms. Fossils were failures of nature, or forms without life. He speculated, however, that actual plant and animal remains might have been turned into stone by forces of petrification.[36] Such was a tree of which he wrote that, together with a bird's nest in it, complete with birds, was petrified by a formative or plastic virtue in nature, the mineral virtue of Avicenna and the _vis formativa_ of Aristotle.[37] As Albertus noted:

> There is one who is not astonished to find stones which, both externally and internally, bear the impression of animals. Externally they show their outline and, when they are broken open, there is found the shape of the internal parts of these animals. Avicenna teaches us that the cause of this phenomenon is that

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[33] Sarton, _Introduction_, II, pt. 2, 938; and Duhem, pp. 309-317.

[34] Sarton, _Introduction_, II, pt. 2, 938; and Duhem, pp. 309-317.

[35] Zittel, p. 13.

[36] Geikie, p. 13; and Adams, p. 254.

[37] Albertus Magnus, _Liber mineralium_, [Oppenheym, 1518], Bk. I, vii, 14.

> animals can be entirely transformed into stones and particularly into salt stones. Just as earth and water are the usual matter of stones, he says, so animals can become the matter of certain stones. If the bodies of these animals are in certain places where a mineralizing power [*vis lapidificativa*] is being exhaled, they are reduced to their elements and are seized by the qualities peculiar to these places. The elements in which the bodies of these animals are contained are transformed into the element which is the dominant element in them: that is the terrestrial element mixed with the aqueous element into stone. The different external and internal parts of the animal keep the shape which they had beforehand.[38]

Albertus cited as evidence of this remains of marine creatures found in rocks on mountains. Water had deposited them, cloaked with mud, within stones, where cold, dry conditions preserved them from putrefaction. Round marine shells of these origins could be seen in stones near Paris.[39]

Another thirteenth-century writer to propound a theory on the origin of fossils was Ristoro d'Arezzo (fl. c. 1282). He was the author of a treatise on the composition of the world, *Della composizione del mondo colle suė cagioni* (1282).[40] D'Arezzo advanced the opinion that mountains were once under the sea, because of the finding of fishbones and sand upon their summits. These aquatic remains had been placed there by the Noachian

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[38] *Ibid.*, [illegible] I, vii, [illegible].

[39] *Ibid.*

[40] Haber, p. 43; Sarton, *Introduction*, II, pt. 2, 928-29; and Duhem, 319-23.

Deluge.[41] D'Arezzo also conceived of a petrifying force within the water, a force that could create mountains of stone as well as smaller concretions which were formed around the shells of molluscs.[42]

Two centuries after D'Arezzo's work, Leonardo da Vinci (1452-1519) turned his attention to fossils.[43] Da Vinci was opposed to the theory that fossils had been deposited by the Deluge. He granted that the Flood had occurred and that it did cover the highest mountains, but he argued that shells should be found on the sides of mountains, and not where they are found, near the bases, neatly arranged in layers.[44] Moreover, the waters could scarcely have swept heavy live shell animals so high, nor could the creatures have traveled in the furrows they made the two hundred and fifty miles to the mountains of Lombardy from the Adriatic in the forty days' time of the Flood.[45] Da Vinci proceeded to cite other factors to support his opinion. The turbid waters of the Flood would have deposited the shells in a chaotic fashion, but instead they were

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[41] Adams, 339-40; and Duhem, 319-23.

[42] Adams, 339-41.

[43] Zittel, p. 14; and Geikie, pp. 50-51.

[44] Leonardo da Vinci, The Notebooks of Leonardo da Vinci (Arranged, translated, and introduced by Edward MacCurdy, 2 vols.; New York: Reynal & Hitchcock 1938?), I, 349.

[45] *Ibid.*, 350.

found in colonies and in regular rows grouped in layers as were living ones.[46] The Flood could not have carried the shells, because things heavier than water do not float upon the surface of waves, which would have been necessary to leave them at the heights where they are now.[47] The river and other inland currents were stronger than ocean currents; when the opposing waters met, as in the Deluge, the inland currents would have agitated the bottom of the sea and swept all movable objects before them.[48] The sea could not have risen so high by itself, because the resulting flood would have been so great as to form a vacuum in the sub-oceanic caverns from which the sea-water would have been drawn. Leonardo, a good Aristotelian, needed something to prevent the impossible existence of a vacuum. Air could not suffice to do this, because lighter objects cannot support heavier ones.[49] The water for the Deluge, therefore, must have been rain water. If the water flowed down to the sea, then, instead of from the sea inland, shells would have been pushed away by the stronger inland currents.[50]

Furthermore, Leonardo was against either a universal or a series of deluges. As for the former, Leonardo noted that there were places where there were no visible traces of marine earth or sea shells.[51] To the latter, he said

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[46]<u>Ibid.</u>, 351. [47]<u>Ibid.</u>, 352. [48]<u>Ibid.</u>, 353.

[49]<u>Ibid.</u> [50]<u>Ibid.</u>, 353-54, 358. [51]<u>Ibid.</u>, 352.

that it would require a deluge every year in order to produce the even layers of stone, each of which contained shells.[52]

The theory that fossils were generated by celestial influences operating within the earth fared no better with Leonardo.[53] He inquired as to how this influence produced in the same place different kinds of shells, of various sizes and ages.[54] Implying that there was no answer by means of this theory, he marshalled forth anatomical and morphological evidence against it:

> How another set of ignoramuses maintain that nature or the heavens have created them in those places through celestial influences; as though in those places one did not find the bones of fishes which have taken a long time; as though one could not count on the shells of cockles and snails the number of the months and years of their lives, just as one can on the horns of bulls and wethers [rams] and in the ramifications of plants when they have never been cut in any part. And having shown by these signs that the length of their life is evident, it must needs be admitted that these animals could not live without the power of movement in order to seek their food, and we cannot see how they are equipped with any instrument for penetrating the earth or stone in which they find themselves enclosed. But how could one find in the shell of a large snail fragments and bits of many other sorts of shells of different kinds unless they had been thrown into it by the waves of the sea as it lay dead upon the shore like the other things which the ocean casts up on the land.[55]

Leonardo answered the question of the origin of aquatic remains by referring to the operation of natural forces, which he believed acted in a uniform manner.[56]

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[52] *Ibid.*, 358. [53] *Ibid.*, 356. [54] *Ibid.*, 332.

[55] *Ibid.*, 357. [56] *Ibid.*, 361.

Rivers constantly carried mud and other objects from the highest mountains, down through valleys, and to the sea. When this silt approached the ocean, it often trapped shell animals, killing them. The insides of these creatures rotted away, and were replaced by mud. Eventually the mud both around and inside the shell was petrified by a viscous and petrifying moisture which, reacting with the mud, formed a sticky paste. The paste then dried, becoming stone.[57] Successive layers of stones containing shells, leaves, seaweed, and other objects, were formed in this manner, either by autumn floods or by earth thrown up by the sea. These strata continued to mount until they emerged from the sea and became mountains. At this stage the natural processes began anew, and erosion bared the shells to human view.[58]

The principles of stratification that Leonardo had established--erosion, fossil deposition, and petrification of strata--were not completely satisfactory to him, for they did not adequately explain how the shell beds had reached such immense heights. Consequently, he resorted to an explanation based largely upon the theoretical efforts of Albert of Saxony (1316?-1390).[59]

The earth, according to this theory, contained a

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[57]Ibid., 330-31. [58]Ibid., 331-32, 357.

[59]Duhem, Études sur Léonard de Vinci, ceux qu'il a lus et ceux qui l'ont lu (Première série, Paris: F. De Noble, 1955), 1-50; and Sarton, Introduction, II, pt. 2, 1428-32.

huge cavern beneath the surface, which was filled with water. Part of the cavern, pierced by springs which had gradually worn out a large space, had collapsed inward toward the center of the earth. This caused a subsidence of land above ground. It also brought about an elevation of land, because the world has both a fixed center and an actual center, or, in Aristotelian terms, a center of form, which is the fixed center of the universe, and a center of weight, which is the irregular center. These centers are not the same, because the combined gravity of the irregular earth and that of the water balance in equally heavy opposite positions about the center of weight. The earth and the water are not, then, equally distant from the center of the universe, because of the irregularity of the earth's surface. When erosion occurs, as in the case of springs, there is a loss of weight towards the center of form. The need for a balance of weights at the irregular center will cause the earth to rise in another part. The water, however, being fluid, does not change its distance from the fixed center. It merely covers the fallen land. Thus a regularity is established between the surface amount of land and water.[60] This could

> . . . be the reason why the marine shells and oysters that are seen in the high mountains, which have formerly been beneath the salt waters, are now found at so great a height, together with the stratified rocks,

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[60]Leonardo, Notebooks, I, 372-74.

> once formed layers of mud carried by the rivers in the lakes, swamps, and seas; and in this process there is nothing that is contrary to reason.[61]

Leonardo had established a system of geological dynamics based upon uniformitarian processes at work in nature. In so doing, he had relied far more upon authority than he had upon observation. Nevertheless, he made a strong appeal for the value of empirical evidence:

> Since things are far more ancient than letters, it is not to be wondered at if in our days there exists no record of how the aforesaid seas extended over so many countries; and if moreover such record ever existed, the wars, the conflagrations, the changes in speech and habits, the deluges of the waters, have destroyed every vestige of the past. But sufficient for us is the testimony of things produced in the salt waters and now found again in the high mountains, sometimes at a distance from the seas.[62]

It is difficult to assess the value of Leonardo's work because his notes, although they were written about 1508, did not appear in print until centuries later.[63] It is probable that since his manuscripts circulated primarily among collectors, they had little influence on later scientific thinkers.[64] Moreover, developments occurred which largely undermined the validity of his statements. The Aristotelian cosmogony upon which he had relied so heavily was being contested by newer world systems.[65] The

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[61] *Ibid.*, 374. [62] *Ibid.*, 363.

[63] *Ibid.*, 43-49. See also Geikie, p. 14; and Haber, p. 48.

[64] Leonardo, *Notebooks*, I, 45-49.

[65] Haber, pp. 48-49.

Reformation, which erupted about the time of his death, reasserted the authority of Genesis and the corresponding need for a Noachian Deluge and for a limited time period since the creation.[66] In addition, there were other theories about fossil remains.[67]

These various theories included the notion of the creation of fossil remains by means of astral influences trapped within the earth; the belief that fossils sprang from living seeds deposited in the earth by vapors which blew in from the sea and which were driven down as rain; the idea that some living force within the earth had created fossils either as freaks or "sports" of nature, or as a variation of mineral forms; and finally, the view that fossil forms were the remains of once-living plants and animals. This last theory, when accepted, usually included the corollary that these creatures were vestiges of the early creation, left where they are now by the Flood of Noah.[68]

There were those, however, who believed in the organic origin of fossil remains but not that the Flood had deposited them. Girolamo Fracastoro (1483-1533), writing about excavations in Verona, noted that the fossils that were raised there by the diggings were not the result

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[66] Ibid. See also Geikie, p. 46.

[67] Zittel, pp. 13-17; and Adams, pp. 250-58.

[68] Geikie, pp. 13-14, 20.

of a plastic force, but were the remains of marine animals. These animals had lived and died where they were found. The Flood had not brought them, because it was of temporary duration. It could only have brought fresh-water mussels, not the marine mussels found there. Furthermore, the Flood would have strewn the mussels about, rather than buried them.[69]

Girolamo Cardano (1501-1576) believed that fossils were evidence that the sea had once covered the hills, but rejected the idea that a universal flood had deposited them.[70]

Another of this sixteenth-century group was the self-educated Huguenot potter, Bernard Palissy (c. 1510-1590).[71] Palissy began his discussion of fossils with an attack on Cardan. Palissy declared false Cardan's opinion that the Flood had once covered the world and left shells behind where it resided.[72] Palissy was in error, for Cardan

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[69]Girolamo Fracastoro, Hieronymi Fracastorii Homocentrica. Eivsdem De cavsis criticorvm diervm per ea qvae in nobis svnt. ([Venetiis], 1538), pp. 1-4.

[70]Girolamo Cardano, De svbtilitate libri XXI. Nunc demum ab ipso autore recogniti, atque perfecti (Lvgdvni: Apud Gulielmum Rouillium, 1559), Bk. II, p. 121.

[71]Zittel, p. 18; Haber, p. 49; Geikie, 104, 118-19; and Adams, pp. 261, 446-47.

[72]Bernard Palissy, Discovrs admirables de la natvre des eavx et fonteines, tant natvrelles qv'artificielles, des metaux, des sels & salines, des pierres, des terres, de feu et des emaux. Avec plvsievrs avtres excellens secrets des choses naturelles. Plvs vn traite

himself had argued against the deposition of fossil shells by the Flood.[73]

Palissy had three arguments against the deposition of shell fish in the rocks by the Flood. First, when a violent storm broke out, signalling a major upheaval on the waters, all the forms of life that dwelt in and around the ocean scurried for safety. Fish commonly went to the ocean floor; shell fish clung to rocks on the bottom. There they would have weathered the storm, and avoided being scattered over the land.[74]

His second argument was that the waters of the Deluge inundated the land in the form of rain, and not by flood from the sea.[75]

Thirdly, Palissy thought it absurd that the sea could put shells into rocks. He described large rocks from a quarry located upon a mountain overlooking the city of Sedan. Shellfish were found inside all of these rocks, even the hardest. It was obvious to him that the rocks had

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de la marne, fort vtile & necessaire, pour ceux qui se mellent de l'agriculture. Le tovt dressé par dialogves, esquels sont introduits la theorique & la practique (Paris: Martin de Leune, 1580), pp. 155-56. An English translation is Bernard Palissy, The Admirable Discourses of Bernard Palissy, trans. Aurele La Rocque (Urbana, Illinois: University of Illinois Press, 1957).

[73]See Cardano, De svbtilitate, Bk. II, p. 121.

[74]Palissy, Discovrs, pp. 156-57.

[75]Ibid.

once contained openings through which fish swam in channels of water. At some time both the fish and the water petrified.[76]

Palissy developed his own theory of why fossil shells were found so far from the sea. He began by remarking that the earth produced in its rivers, brooks, and fountains nearly as many shellfish as the sea did.[77] This was true because one found thousands and millions of petrified shells, which were obviously the remains of animals caught and eaten by men.[78] He concluded, therefore, that those shellfish were born and were petrified in the quarries where they were discovered. As an example, he examined shellfish which had lived in a large lake.[79] The lake had become filled with salsitive and generative seed, and this, together with the earth about it and the fishes within it, congealed. Palissy believed that this same process also occurred in sea water. He apparently employed observation to confirm this latter statement, because he wrote that he had cut away a large rock from a cliff near Soubize. The rock formerly was covered by sea water, and it now contained many varieties of shellfish.[80]

Palissy continued his observations, and one of

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[76] *Ibid.*, pp. 161-62, 221-22. [77] *Ibid.*, p. 157.

[78] *Ibid.*, p. 158. [79] *Ibid.*

[80] *Ibid.*, p. 160.

their most important results was his idea that a connection existed between fossil shells and living shellfish. He saw a resemblance between the petrified mussels in the Ardennes Mountains and those living in the nearby Meuse River.[81] He hunted and collected near Venteuil, where he observed large numbers of different kinds of shellfish similar to those in the ocean, including purple shells and whelks. Some of the shells had not petrified. These, he reasoned, were just as they had been when the fish were in them.[82] He went to a mountain near Soissons, where there were thousands of petrified shells--too many, Palissy thought, to have been born and petrified in any place except that in which they were discovered. Many of these resembled living shellfish.[83]

Palissy was convinced that these shellfish that he had examined had not lived in the sea at one time. He admitted that he thought that they had likeness to living marine shellfish, but he explained that this ". . . must convince us that in many places of the earth the waters are salty, not so much as those of the sea,--but they are salty enough to produce all sorts of shellfish."[84]

Another conclusion that Palissy drew from his observations was that some of the fossil forms that he had

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[81] Ibid., pp. 162, 222. [82] Ibid., p. 163.
[83] Ibid., p. 225. [84] Ibid., p. 223.

observed had no living counterparts. At Venteul, he had enumerated eleven kinds of fossils, yet he found some varieties in the Ardennes and Champagne regions which he considered previously unknown.[85] All that remained of some of these fish were their shells or their impressions in the rocks. Others he thought similar to certain purple shells, whelks, and other large snails, samples of which were brought by sailors from the Indies and Guinea.[86]

Palissy examined and gathered other substances he believed to be petrified, such as wood, and he kept a cabinet of his finds, as did many other people who studied fossils, both before and after his time.[87] His collection included a petrified quince, a fig, a turnip, and a pear, the last of which he lost. He also observed the collections of others. For instance, a surgeon showed him a whole petrified crab. In addition, he saw petrified chestnuts and a flower turned to stone.[88]

The method by which all these fossils were preserved was considered by Palissy in his discussion about metals and alchemy. He said that the origin of all natural things was water. Within ordinary water there existed special, congelative waters. One of these waters caused

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[85] Ibid., pp. 164, 225-26. [86] Ibid., pp. 164, 226.

[87] Ibid., pp. 166, 230. [88] Ibid., p. 231.

the generation of trees and plants.[89] There were other special waters as well, including metallic and crystalline waters, which changed things to metal and stone, respectively.[90] He examined many varieties of wood which he thought had turned to either metal or stone. He also found fish as either metal or stone; he said that near Mansfeld there were many metallic fish.[91] Palissy concluded that the action of congelative water could reduce all men, plants, and animals to rock,[92] and that fluid metallic materials could similarly change them to metal.[93]

Though Palissy did not speak of organic remains as fossils, because he employed the term fossil in a larger sense, he clearly believed them to be traces of plants and animals.[94] He denied both the Flood and that the sea had once been where the land now was. He explained how fossils were found so far from the sea, and he thought that there was a connection between fossil shells and living forms. He noted that some fossil forms were now extinct. He collected and enumerated different kinds of fossils. Finally, he described the petrification process that preserved fossil forms.

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[89] _Ibid._, pp. 105, 128-29. [90] _Ibid._, pp. 129-30.

[91] _Ibid._, p. 130. [92] _Ibid._, pp. 150-51, 242.

[93] _Ibid._, pp. 106-107, 129-31, 150, 368.

[94] _Ibid._, pp. 252, 380.

There were many other different contemporary opinions to explain the nature and origin of fossils. For example, Georg Bauer (1494-1555), better known by his Latin name of Georgius Agricola, published his _De natura fossilium_ in 1546. In this work, Agricola discussed both formed stones and fossils. He believed that some stones have shapes that were similar to those of familiar objects.[95] Such were the _Ammonis cornu_ which resembles a horn; _belemnites_, an arrow; _lapis judaicus_, an acorn; _lapis molaris_, a tooth; _enorchis_, the testes; _diphyis_, male and female genitals; others, pieces of wood; _entrochos_, a wheel; and _enostos_, bones.[96] He described and listed the medicinal functions of such formed stones as the _lapis judaicus_, the _etenites_, and the _ostracites_.[97] These were made, as were all other minerals, from solidified accumulations of

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[95] Georgius Agricola Georg Bauer , _De ortu & causis subterraneorum lib. V. De natura eorum quae effluunt ex terra lib. IIII. De natura fossilium lib. X. De ueteribus & nouis metallis lib. II. Bermannus, sive de re metallica dialogus. Interpretatio germanica uocum rei metallicae, additio indice foecundissimo._ Basileae: [Per Hieronymvm et Nic. Episcopivm, 1546], p. 171. Hereafter cited as Agricola, _De natura fossilium_. An English translation is available of a portion of this work, _De natura fossilium lib. X._, in Mark Chance Bandy and Jean A. Bandy (trans.), _De natura fossilium (Textbook of Mineralogy)_ ("The Geological Society of America Special Papers," No. 63; New York: The Geological Society of America, 1955).

[96] Agricola, _De natura fossilium_, p. 181.

[97] _Ibid._, pp. 265-69.

water.[98] He remarked that certain of these rocks, when cut open, were discovered to hold shells, such as the conchites beds in Megara, and snail shells in French rocks.[99] He also observed that transparent amber contained gnats, fleas, ants, spiders, small eggs, fish eggs, tree leaves, plant stalks, and little things. For these, Agricola postulated an organic origin, and provided for their petrification with an apparently new concept, a petrifying juice, or succus lapidescens.[100] This juice was mixed with water, and caused some springs and rivers to petrify gloves, bones, and other substances without changing their form. This had happened to animal bones excavated near Hildesheim, as well as to the bones of an unknown marine monster and to fish teeth observed at Lunenberg. Agricola mentioned, but did not countenance, Theophrastus's belief that stones which resembled bones were produced within the earth.[101]

Conrad Gesner (1516-1565) treated fossils in a broad sense, as anything dug from the earth, in the first illustrated work upon this subject, his De omni rerum fossilium genere . . ., which appeared in Zurich in 1565.[102]

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[98] Ibid., pp. 184-85. [99] Ibid., p. 322.

[100] Ibid., pp. 51-57, 247-48, 323-25, 327.

[101] Ibid., p. 327.

[102] Konrad Gesner, Conradi Gesneri de rerum fossilivm, lapidvm et gemmarvm maxime, figuris & similitudimis liber; non solum medicis, sed omnibus rerum naturae ac philologiae studiosis, vtilis & iucundus futurus (Tigvri: [Gesnervs], 1565).

Gesner believed that the formed stones which he had examined were of two origins. Some, which resembled the sun, moon, stars, and other bodies, were, as Theophrastus had said centuries earlier, products of the earth itself, or, in sixteenth-century terms, *lapides sui generis*. Others were petrified remains of animals, whose location Gesner did not explain.[103]

This latter opinion of Gesner, that figured stones were the remains of plants and animals, was held by other writers in the period from the early sixteenth to the late seventeenth centuries. Among these were Andrea Cesalpino (1519-1603) and Fabio Colonna (1567-1650). Cesalpino in his treatise *De metallicis* wrote that the sea had once covered the land.[104] He said that fossil shells that are found today were at one time living organisms in those waters. When the sea retreated, the shells were left behind. These shells were then petrified by subtle influences from nearby rocks.[105]

Colonna in 1616 published his *Opusculum de purpura*, which was a catalogue of fossils containing significant items, such as their illustrated and written descriptions, names of authorities who had written about them, and where

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[103] *Ibid.*, pp. 35-37, 162-63.

[104] Andrea Cesalpino, *De metallicis libri tres* (Romae: Ex typographia Aloysij Zannetti, 1596), pp. 133-134.

[105] *Ibid.*, pp. 132-34.

they might be found. The most penetrating thing he included, however, was in the Dictionarium Ostracologicum, a chapter of addenda on testaceous animals arranged in alphabetical order. It was his Dissertatio de Glossopetris. In it, Colonna argued that the Glossopetrae found upon the island of Malta were not the tongues of serpents, but instead the teeth of dog-fish, or sharks. Their similarity in shape to the teeth of living sharks, the fact that they were of osseous and not of stony matter, their location, and their reaction to chemical tests indicated this. Moreover, these Glossopetrae were found in layers with the remains of other creatures, such as the shells of snails and of bivalve marine animals.[106] Colonna also noted that the remains of terrestrial animals and plants could be seen in other layers. He was convinced that all these fossils that he had examined in his dissertation were of organic origin and were not the result of crystalline or other concretions, nor were they caused by any force acting within the earth that spontaneously generated them. Colonna denied the action of a subterranean seminal fluid in creating bones of giants. Finally, he explained repeated discoveries of huge bones by citing authorities to support his belief

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[106] Fabio Colonna, Fabii Columnae Lyncei, Nobilis Neapolitani, Genere Romani, Opusculum de purpura. Romae primium, An. 1616. editum, & nunc iterum Luci datum Opera ac Studio Johann-Danielis Majoris. Cujus novissime accesserunt annotationes quaedum (Kiliae: Joachim Reumannus, 1675), pp. 39-41.

that enormous men had and still did exist, and that they were the origin of these bones.[107]

In addition to the views of Cesalpino and Colonna, a host of other explanations were advanced to explain the fossil phenomena. One of these explanations provided by Pietro Andrea Mattioli (1500-1577), a botanist, who described the fossil fish of Monte Bolca.[108] Mattioli thought that it was possible that the great number of shells and bones that were found in Italy might have been made into stone by means of a petrifying juice, or succus lapideus. He believed, though, that the several types of shells and bones demanded several types of juices. He did not speculate upon the origin of these fossil remains.[109]

Gabriello Fallopio (1523-1562) believed that fossils were figured stones which had been generated by subterranean vapors. These vapors were produced by a process of fermentation that occurred in the rocks where they were located.[110] Fallopio thought it more reasonable

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[107] Ibid., pp. 42-43.

[108] Pietro Andrea Mattioli, Commentarii, in libros sex Pedacii Dioscoridis Anazarbei, De medica materia. Adiectis quam plurimis plantarum & animalium imaginibus, eodem authore (Venetijo: Vincentium Valgrisium, 1554), pp. 563-69.

[109] Ibid.

[110] Johann Christian Poggendorff, Biographisch-Literarisches Handworterbuch zur Geschichte der exacten Wissenschaften enhaltend Nachweisungen über Lebensverhältnisse und Leistunger von Mathematikem, Astonomen, Physikern, Chemikern, Mineralogen, Geologen usw aller Völker und Zeiten (2 vols.; Leipzig: Johann Ambrosium Barth, 1863), I, 718; Geikie, p. 52; Zittel, p. 16; and Adams, p. 255.

to assume that this was the origin of the fossils that he had seen, fossils which resembled elephant bones, shark teeth, and shells, than to suppose that the Deluge had reached as far as Italy and deposited them there. This belief in the formative power of underground vapors probably led Fallopio to assume that the urns, pots, and other earthenware vessels which were excavated at Monte Testaccio in Rome were natural productions of the earth, generated in the same manner as other figured stones.[111]

Some of these theorists also assembled collections of fossils; others collected but did not theorize. Michele Mercati (1541-1593), one of the former group, described and illustrated a mineral collection of Pope Sixtus V (1585-1590), which had been gathered at the Vatican. It included many fossil shells. Mercati denied that these fossils were of organic origin, and concluded that they were formed by celestial influences.[112] Olivi of Cremona (fl. 1584) in 1584 described as sports of nature the fossils in the Calceolarian collection in Verona.[113] Johann Kentmann (1518-1574), a Würtemberg physician who supposedly

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[111]Geikie, p. 52; Zittel, p. 16; and Adams, p. 255.

[112]Michele Mercati, Metallotheca opus posthumum, auctoritate, & munificentia Clementis Undecimi Pontificis Maximi e tenebris in lucem eductum, opera autem, & studio Joannis Mariae Lancisii archiatri pontificii illustratum (Romae: Ex officina Jo. Mariae Salvioni, 1717), pp. 215-20, 294-96.

[113]Geikie, pp. 52-53; and Zittel, p. 16.

was the first man in Europe to make a collection of minerals, published a small book on his acquisitions in 1565.[114] Kentmann's work contained a plate that showed his cabinet of fossils, or things dug from the earth. It also presented a long annotated list of minerals with Latin names, often with German translations. Kentmann offered a survey of minerals divided into classes, giving their names, where they could be found, and other information. Some remains which resembled plants and animals were included among Kentmann's mineral divisions.[115]

Johannes Bauhin (1541-1613) in 1598 described the fountain at Boll, and included in his description figures of ammonites, belemnites, and other fossils that he found in the shales. As Kentmann, Bauhin did not speculate upon the origin of his finds.[116]

Many were busy at this time gathering fossils and establishing fossil collections. Among these other collectors were Ulisse Aldrovandi (1522-1605) and Olao Worm (1588-1654). Aldrovandi, who held the chair of

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[114] Johann Kentmann, Catalogvs rervm fossilium, ed. Konrad Gesner (Tiguri: Iacobus Gesnerus, 1565); Zittel, p. 16; and Adams, pp. 195-96.

[115] Kentmann, Catalogvs.

[116] Johann Bartholomew Adam Beringer, The Lying Stones of Dr. Johann Bartholomew Beringer being his Lithographiae Wirceburgensis, trans. and annot. Melvin E. Jahn and Daniel J. Woolf (Berkeley, California: University of California Press, 1963), pp. 114, 181. Hereafter cited as Beringer, Lying Stones. See also Geikie, p. 16.

Natural History at the University of Bologna, left to be published after his death materials entitled Musaeum Metallicum (1648).[117] This work was composed of four books, the third book treating with succi concreti, or a petrifying juice, and the fourth with stones. Each book contained several chapters on various subjects, with no apparent arrangement. Some of the headings, such as Sympathia et Antipathia, Mystica, and Somnia, treated of mystical topics. The most pronounced feature of Aldrovandi's discussions were, however, the many woodcuts, some of full-page length, which illustrated the book.[118] Fossil shells were very well reproduced, as were imitative forms of plants, animals, and parts of the human body, which spontaneously grew in the form of stones.[119] Aldrovandi believed in the action of some strange force in nature that produced these oddities, for he also presented illustrations of other mysteriously-made subjects, such as pictures of Christ and the saints, shell-fish, large teeth, Tartars who were petrified together with their camels and sheep,

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[117] Ulisse Aldrovandi, Vlyssis Aldrovandi, patricii Bononiensis, mvsaevm metallicvm in libros IIII. distribvtvm Bartholomaevs Ambrosinvs in patrio Bonon., archigymnasio simpl., med. professor ordinarius, musei illustrissmi., senatus Bonon. et horti publici prefectus, labore et studio composuit, cum indice copiosissimo, Marcvs Antonivs Bernia proprijs impensis in lucem edidit ad serenissimvm Ranvtivm II Farnesivm Parmae Placentiae etc. Dvcem VI. Bononiae: Typis Io. Baptistae Ferronij, 1648 .

[118] Ibid. [119] Ibid.

and other remains.[120] Throughout all his work, Aldrovandi was primarily interested in the medicinal and occult properties of the rocks, minerals, and gems, which properties he often confused with each other, and in citing the ideas of others rather than in employing his own.

Aldrovandi did not speculate about fossils. He did collect, establish a museum or cabinet of his collections, and publish illustrations of them. This activity made simpler the identification and collection of fossil remains.[121] It was now possible to compare fossils with illustrations in books, and to create classification systems more easily. There was thus fresh material to inject into the background of received ideas. Consequently, works such as Aldrovandi's were much in demand for reference purposes.

Worm wrote the Museum Wormium.[122] Worm, a Regius Professor of Denmark, published this work as a catalogue of his notable collection of natural and artificial rarieties.[123] He believed that fossils were spontaneously formed within the earth, and also felt that fossils of one species could readily turn into another species.[124] His

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[120] Ibid., pp. 816, 955-66.

[121] Beringer, Lying Stones, p. 162.

[122] Ibid., p. 163.

[123] Adams, p. 97.

[124] Beringer, Lying Stones, p. 163.

definition of fossils was typical for those who believed in the spontaneous generation of these forms:

> Now a fossil is a perfectly mixed body, inanimate, without life, endowed by God at its creation with a peculiar form and a seminal power ennabling it to procreate its like and to propagate itssspecies.[125]

Besides these major figures, there were many lesser contributors in the gathering of fossil collections. These men included Ferrante Imperato (1550-1625), Goropius Becanus (1518-1572), and Caspar Schwenckfeld (1563-1609), besides the aforementioned Mattioli, Kentmann, and Olivi.[126] Imperato's work was, as Aldrovandi's, encyclopedic in nature, and it was illustrated. Imperato attributed the formation of stones that had the shapes of plants and animals to a petrific juice that operated from beneath the surface of the earth.[127] Schwenckfeld, a Hirschberg physician, published a catalogue of fossils in Silesia, but did not speculate upon their origin.[128] Becanus, or Johannes

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[125] Ibid.

[126] Charles E. Raven, John Ray, Naturalist: His Life and Works (Cambridge: At the University Press, 1942), p. 423.

[127] Ferrante Imperato, Dell 'historia natvrale di Ferrante Imperato Napolitano. Libri XXVIII. Nella qvale ordinatamente si tratta della diuersa condition di miniere, e pietre. Con alcune historie di piante, & animali, sin' hora non data in luce (Napoli: Constantino Vitale, 1599), p. ix; and R.[obert] P.[lot], The Natural History of Oxford-Shire, Being an Essay toward the Natural History of England (Oxford: Printed at the Theater, 1677), pp. 672-74.

[128] Kaspar Schwenckfeld, Stirpium & fossilium catalogus (Lipsiae: Albert, 1600).

Goropius, compiled a catalogue of antiquities entitled Origines Anterpianae.[129] In it, he dismissed as nothing more than the molar of an elephant, a huge tooth, long thought, he said, by others to be that of a wicked giant. He also attributed as elephant remains two huge skeletons dug up near Wielworda. Becanus probably believed that formed stones had been generated by a lapidific juice, but he appeared somewhat confused on this issue.[130]

Speculation upon the origin of fossils continued into and throughout the first half of the seventeenth century. Among these many speculators were Andreas Libavius (d. 1616) and Albaro Alonso Barba (fl. 1640). Libavius was interested in impressions shaped like living creatures which were found within rocks, such as those of insects, frogs, and fish.[131] Libavius thought that these

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[129]Beringer, Lying Stones, p. 167.

[130]Ibid.

[131]D. Giacinto Gimma, Della storia naturale delle Gemme, della Pietre, e di tutti i Minerali, ovvero della Fisica Sotterranea, in cui delle Gemme, e delle Pietre stesse si spiegano la Nobilta, i Nomi, i Colori, le Spezie, i Luoghi, la Figura, la Generazione, la Grandezza, la Diviezza, la Madrice, l'Uso, le Virtu, le Favole: se al suoco resistano: quali sieno nella Sagra Scrittura nominate: quali i Simboli: ed altre notizie, che alle medesime appartenzono. Si da ancora la cognizione de Metalli, delle Terre, de 'Sali, de' Solsi, de' Biturni, delle Acque diverse di quelche si tratta nella Storia de' Fossili, che dalle Pietre si formano: delle Caverne, della Acque, e de' Fuochi sotteranei, de' Vulcani del Mondo, e di quanto si esamina nella Fisica sotteranea; oltre alcuni Trattati valevoli a dilucidare la Storia tutta della Minerali, ed altri, che della Vegetevole, e di quella

forms were the remains of once living things. They had been produced by seeds, or seminal forces carried by winds or rains, which were constantly in widespread operation throughout nature. These seeds had been brought into the rocks by means of permeating waters, which washed them down into tight spots in porous rocks. There the seeds became lodged, and grew and developed into mature forms. Libavius also noted that fossil fish were found in black shale near Mansfeld in Saxony, which he believed were made of a metallic matter. He wrote that they were probably so made because the water that carried the seed brought with it the metallic matter.[132]

Barba, writing somewhat later than Libavius, was exploring new territories, for he was one of those Europeans who was going all over the world, taking their scientific curiosity with them. Barba was director of the mine of silver located at Potosí in Peru, and he employed some of his leisure time observing stones collected from the high Andes Mountains.[133] Barba was puzzled about the existence of stones which had the shapes of animals,

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degli Animali, sono proprjo. Divisa in Libri VI. o Tomi II. Colle Tavole de' Capitoli nel primo: de' Nomini delle Pietre, e delle cose notabili nel secondo. (2 vols.; Napoli: Nella Stamperia di Gennoro Muzio, 1730), II, 236. Hereafter cited as Gimma, Della storia naturale. See also Poggendorff, I, 1450.

[132]Gimma, Della storia naturale, II, 236-37.

[133]Adams, p. 256.

plants, shells, and other living things, and he could not believe that all these stones were the remains of living creatures.[134] He had seen trees, limbs and bones of beasts, wood debris from the Plata River, and what he thought were the bones and teeth of giants excavated at Tarija, all of which he believed had become petrified. He was convinced that this had occurred because these substances had been porous and had become permeated with a petrifying liquor.[135] Some substances, however, could not have been reproduced in stone, such as soft and gentle substances, because they did not possess the temperament to withstand the force of petrification. Therefore, no hands, feet, leaves, fruits, or flowers were found that had become stone. The Aristotelian ideas of form, virtue, disposition, and temperament could not have allowed such productions.[136]

Nevertheless, there were strange forms in stone that Barba could not explain, except to say that they were formed by the Creator himself. Among these rarieties were stones with snakes upon them, one with the chair of Solomon

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[134] Albaro Alonso Barba, _Arte de los Metales, en que se enseña el verdadero beneficio de los de Oro, y Plata por Açoque_ (Madrid: Imprenta del Reyno, 1640), pp. 45-47. Hereafter cited as Barba, _Arte_. An English translation is Albaro Alonso Barba, _The Art of Metals, in Which Is Declared the Manner of their Generation, and the Concomitants of Them. In Two Books_. Trans. Edward Earl of Sandwich (London: Printer for S. Mearne, 1674), pp. 45-47.

[135] Barba, _Arte_, pp. 11, 45-46.

[136] _Ibid_., pp. 11-12, 46-47.

impressed upon it, and still another with the picture of John the Baptist, attired in camel-skin, on it. Barba was only sure that these were wrought purposely for some unknown end, and expressed his marvel at the extent of nature's productions.

> Hallanse a las faldas de los montes Misnenses, junto a la laguna de Alsacia, en la superficie de las piedras, figuras relevadas de ranos, y de pezes, de cobre fino, y son tan ordinarias, y tan propias como ignorada su causa. Llamauan antiguamente Conchites a un genero de piedra, que muy al vino representaua en sus declineaciones las conchas de la mar, pensavan, que estas con el tiempo largo, compañia de piedras, y del jugo que las cria, se avian convertido en ellas, y hazian argumento, de que en tiempos passados huviesse bañado el mar el territorio de la ciudad de Magara, donde solamente se hallauan. Pero oy no tiene lugar este modo de pensar, sirviendo de desengaño la maravillosa veta, o fuerte de piedra parda aherrumbrada, y en partes amarilla, que està en el camino que desta Villa va al valle de Oronesta, quando ya se quiere baxar a el. Hallanse en ella notable variedad de figuras, impressas con tanto primor, que a otro que el Autor de la naturaleza le fuera impossible el estamparlas. Algunas tengo en mi poder, en que se ven conchas mayores, medianas, y mas pequeñas, impressas unas por su parte concaua, y otras por la convexa, con perfectissima delineaciõ de las mas minimas de sus senales. Està esto en el coracon de la tierra firme, y mas doblado, y montuosa deste Reyno, y fuera locura pensar que huviesse la mar en algun tiempo inundado esta Provincia, y dexado [u] nas conchas en aquesta sola veta. Hallanse tambien en ellas con indecible perfeccion, figuras de sapos, mariposas, y otras mas extraordinarias, que por serlo tanto, y no escandalizar con su novedad no las refiero, aunque las he oido de personas sidedignas.[137]

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[137] Ibid., pp. 16-17: "At the foot of the Misenian Mountains, near the Lake of Alsacia, stones are often found which have the images of frogs and fish, in copper, upon their surfaces. Formerly a kind of stone was called conchites, which had its delineations very much like those of cockles from the sea. It was formerly thought that these were fish shells which had

Barba's book marked both the close of the first half of the seventeenth century for the study of fossils, and the last of a long preparatory stage of works upon this subject before the great explosion of books that was soon to follow. Taken together, the written labors of Barba and his predecessors constituted an intellectual legacy.

This legacy provided certain basic ideas that were formulated before 1650, which were to be employed in the half-century after that date.

One of these ideas brought forth was that these fossil remains found within the earth which had shapes similar to animals, and other living things, actually were

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laid a long time underground, where many stones are made, and where the petrifying liquor entered into their pores and changed them into stone. This was believed to be true because it was held certain that all of the country belonging to the city of Megara was once under the sea, and that these shells were only found there. Now, however, this conceit has lost its reasonableness, because of the wonderful veins of stones, some iron-colored, some grey, and some yellow, which are found upon the highway going downhill from Potosí to Oronesta. Here are collected stones that have all kinds of figures upon them, which are so true to life, that only the Author of Nature Himself could have effected such a piece of work. I have some of these stones with me, in which one can see all kinds of cockles, large, medium, and small. Some of them lay up, some down, with every delineation of these shells drawn in great perfection; and this place is in the heart of the country, and in the doubly-most mountainous areas. Here it would be mad to dream that the sea had ever covered this land, and left cockles only in one section. There are also found in these stones perfect likenesses of toads and butterflies, and even stranger figures of whose existence reliable witnesses have informed me. Yet I would not mention these, for fear of straining the credulity of the reader."

organic remains, because of their shapes. This concept prompted a host of arguments both for and against its validity, and was a matter of dispute into the eighteenth century.

Another idea that caused debates was that the forces of nature operated slowly over immense periods of time, in an orderly fashion which was pre-determined by natural laws. This concept, called uniformitarianism in modern times, looked at the past in somewhat the same terms as does an historian, that is, in terms of the present. The uniformitarian reasoned that he could not transport himself to the past to view the world of long ago. In order, then, to discover of what this world consisted, he examined the geological forces at work today, and attempted to deduce from them what he thought that they had accomplished.

Two basic tenets of the uniformitarian credo, the necessity for a long time span and the notion that if the past was not similar to today, at least the forces of nature operating then were the same, was opposed by a contrary idea that neither the world of the past nor the forces of nature at work in it were the same as they were today. Many of the philosophers who held this view believed that the world was growing old and decaying, and that, as a man, it was much more vigorous in its youth. Violence and catastrophe were the watchwords of the past; stagnation and approaching death those of the present. This position, again in modern terms, became known as catastrophism.

Still another view was a compromise between the polar positions of uniformitarianism and catastrophism, and took certain premises from each. Some, for example, believed that catastrophes occurred, but in an orderly sequence. Others thought that a series of sequences of creation and destruction in the world were in the process of occurring. Both of these groups might be classed in a category called uniformitarian catastrophism.

All three of these groups--uniformitarians, catastrophists, and the compromise group--employed or neglected fossil remains at their convenience. It was normal, however, for many theorists of whichever camp to heed fossils, even if only to minimize their significance. Often, though, fossils were taken as one of the critical factors to establish which position one maintained.

One of the pre-1650 ideas was that fossil remains were evidences of geological change. In simple form, it stated that sea-shells found in the hills indicated that the sea had once been there. Implicit in this concept was the belief that a connection existed between the dead fossil shells and living sea-shells dwelling in the ocean depths.

Finally, many of the solutions that explained the nature, origin, and growth of fossils were available to natural philosophers by 1650. Among these ideas were the influence of celestial forces; the creative power of subterranean vapors; the spontaneous generation of fossils by unknown agents; the ability of petrifying liquids or juices to turn objects into stone; and that fossils were organic remains of plants, animals, and other living things.

Besides these fundamental ideas, natural philosophers of the final half of the seventeenth century who were concerned with the study of fossils were also bequeathed four very important trends to affect them in their studies.

The first of these was an antiquarian interest in the past, which caused men to gather and keep ancient items that had been excavated from the earth. The earliest record of such an interest was the collection of the Emperor Augustus, but probably earlier, if not as formal, gatherings were made. This initial step of collection later developed into a more complex form, when larger collections were established which became known as museums. Descriptions were written about these museums, in which fossils were divided into classes, given names, and authorities were cited regarding their natures. Writers began to use both museums and writings about museums to support their conjectures on fossils.

The second was the woodcut illustration, which made it possible to obtain many similar copies of a drawing of a fossil for the purposes of comparison and reference. It also provided a visual tool to supplement verbal description, and it proved to be an aid to investigators in the identification and classification of fossils. Woodcut illustrations were often used after 1565.

The third involved a literal interpretation of the Bible, and it meant that Mosaic history and cosmogony could be considered in theories about fossil origins.[138] It was argued, for example, that excavated fossils could not be of organic origin, because Scripture declared that living things were not made until after the earth's crust was completed.[139] Another argument that the theologians advanced was that if fossils were the remains of plants and animals, then the Deluge of Noah had both destroyed and deposited them in the earth's crust.[140] This religious position was important to those who held that fossils were of organic origin.

Also of note in regard to other theories of non-organic fossil origin was the idea that fossils were either sports of nature or creations of plastic forces in nature. These objects were made by the Creator himself for use as models in later creations or else for some mysterious purpose, such as to test human faith in God.[141]

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[138] Haber, p. 50.

[139] Adams, p. 262.

[140] White, I, 225-27.

[141] _Ibid._, 215-17.

All of these applications of theological dogma to the study of fossils that were in the writings of this time indicated that religion had some effect upon that thought, even though it is impossible to judge to what degree religion could influence any particular natural philosopher's mind. Nevertheless, it is of significance to note that during the last two decades of the seventeenth century, a number of works that concerned fossils were authored that displayed strong theological interests.

The fourth of these developments was the rise of the scientific societies shortly after 1600.[142] First in Italy, later in England, France, and Germany, individuals came together to form social groups wherein matters primarily concerned with natural philosophy and technology were considered.[143] At the meetings of these groups important interchanges of ideas could occur. The societies began to publish learned journals, the most important being the Royal Society of London's Philosophical Transactions and the Journal des Sçavans, which later had close connections to the French Academy of Science.[144] The societies

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[142] Martha Ornstein, The Role of Scientific Societies in the Seventeenth Century (3rd ed.; Chicago, Illinois: The University of Chicago Press, 1938). See also Dorothy Stimson, Scientists and Amateurs: A History of the Royal Society (New York: Henry Schuman, 1948).

[143] Ornstein, pp. 68-69.

[144] David A. Kronick, A History of Scientific and Technical Periodicals. The Origins and Development of the Scientific and Technological Press, 1665-1790 (New York: The Scarecrow Press, 1962), p. 5.

promoted an active intercourse among natural philosophers of all countries. Henry Oldenburg (1626?-1678), Secretary to the Royal Society, remarked, for example, that he was exhausted from writing constantly to over thirty foreign and domestic correspondents.[145] He also translated and had published an English edition of Nicolaus Steno's Prodromus in 1671, only two years after the original appeared.[146] All these labors of the societies helped to bind together an international community of scholars, and allowed ideas about fossils, as well as those upon other subjects of scientific interest, to have a wider and more varied intellectual range.[147]

These remarks are concluded with a warning regarding biases. Most historians of science, as do most acceptable historians in the final third of the twentieth century, write history from an evolutionary, rather than from a revolutionary, point of view. Great stress is laid upon precursors and upon the similarities of any period to its past. A minority, however, reverse affairs. Dorothy Stimson (1890-), for example, in her history of the Royal

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[145]Stimson, p. 68.

[146]Nicolaus Steno, The Prodromus to a Dissertation Concerning Solids Naturally Contained within Solids. Laying a Foundation for the Rendering a Rational Accompt Both of the Frame and the Several Changes of the Masse of the Earth, as Also of the Various Productions in the Same, trans. H. enry O. ldenburg (London: J. Winter, 1671).

[147]Haber, p. 52.

Society, stresses the contrasts between the England of 1600 and that of 1649; Martha Ornstein (1878-1915), in her book on scientific societies in the seventeenth century, similarly emphasizes differences in her discussion on fossils.[148] The evolutionary viewpoint has emerged in this study.

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[148]Stimson, pp. 1-5; and Ornstein, pp. 15-17.

CHAPTER II

FOSSILS AS NON-ORGANIC PRODUCTIONS OF NATURE

The belief that fossils (in a broad sense) which had the shapes of animals and plants, were of other than organic origin, was held by many natural philosophers in the last fifty years of the seventeenth century. They called fossils formed or figured stones. They used many theories to explain these rarities of nature, and they published many books about these fossils.

Those who believed in the inorganic origin thought, in general, that these so-called figured stones were of inorganic origin, and had resulted from some sort of trick or sport of nature, or *lusus naturae*, which was, in turn, the consequence of forces at work within the earth. This view, at least in a primitive form, was already extant as early as the time of Aristotle, and continued to persist, despite attacks, into the eighteenth century.

Among the earlier writers of this period who believed that fossils were non-organic productions of nature were Thomas Nicols (fl. 1659) and Athanasius Kircher

(1601-1680).[1] Nicols held that stones which had the forms of animals or plants were nothing more than oddly shaped stones, which were intriguing because of their uniqueness. In his discussion of the *glossopetrae*, for example, he noted that it was ". . . a stone of the similitude of a tongue."[2] He also mentioned Pliny's description of the stone, listed where it was to be found, and reported its medicinal and occult uses, that is, that it acted as an antidote to both poison and witchcraft.[3] Nature had generated this and other various types of stones from a diverse matter, which was composed of unknown ingredients.[4]

Kircher was, as Nicols, committed to the action of unknown forces and quantities in nature. Kircher, however, was more restrictive than Nicols. Nicols' concepts of a vague Nature and of diverse matter became the narrower but no less vague ideas of a plastic force and of a petrifying

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[1]Thomas Nicols, *A Lapidary: Or, The History of Pretious Stones: With Cautions for the Undeceiving of All Those That Deal with Pretious Stones* (Cambridge: Printed by Thomas Buck, 1652), and Athanasius Kircher, *Mundus subterraneus, In XII libros digestus; qvo divinum subterrestris mundi opificium, mira ergasteriorum naturae in eo distributio, verbo πανταμορφον Protei regnum, universae denique naturae majestas & divitiae summa rerum varietate exponuntur. Abditorum effectuum causae acri indagine inquisitae demonstrantur, cognitae per artis & naturae conjugium ad humanae vitae necessarium usum vario experimentorum apparatu, necnon novo modo, & ratione applicantur* (2 vols. in 1; Amstelodami: Apud Joannem Janssonium & Elizeum Weyerstraten, 1664-65 [vol. 1, 1665]).

[2]Nicols, p. 173.

[3]*Ibid.*

[4]*Ibid.*, p. 231.

power acting upon matter, respectively. For Kircher the beginning of the origin of all things was not nature; it was a universal seed, which was a creative force. This force was known as _panspermia_ in the seventeenth and eighteenth centuries. As Kircher defined _panspermia_, it was a kind of material spirit, which was composed of a very subtle portion either of the elements or else of the celestial mist. The power of this material spirit was drawn from sulphur, mercury and salt--normally three principles in the chemistry of that time. The seed was not, though, composed of these three elements, but was considered to be a vapor which essentially was to be found in these chemical substances.[5]

This seed was a force, and not thought to be alive, because it functioned in the propagation and growth of metals and minerals, bodies which did not possess vegetative and sensitive natures. It was divided into two natural properties given to it by God: the first was a plastic power (_virtus plastica_), that gave an object its figure, color, and form; and the second, a magnetic force (_virtus magnetica_), that enabled things to be created by giving like objects an ability to attract like objects. This seed, Kircher concluded, was all the substance of any composite body, as any individual body was merely the

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[5]Kircher, Bk XII, Sect. i, Ch. 9, p. 349.

product of the interaction between the seed and the principals.[6]

Further complications ensued when Kircher attempted to explain those fossils which had the shapes of plants, animals, and other living things, and he relied both upon his formative force, the _spiritus architectonicus_, or _spiritus plasticus_, and upon a petrifying force, or _vis lapifica_, which was always latent within the earth. This process was described, for example, in his account of imitation giant bones:

> Dico, latere in subterrestribus visceribus intra saxosorum montium hiatus, terram quandam limosam, quam Margam cum _Agricola_ supra nominavimus gypseae materiae mistam: quae terra ubi per rimas montium nitrosum fluorem receperit, fit, ut illa veluti cortice quodam gypseo, induatur, qui uti cum tempore lapidescit, ita quoque salenitri splendore albedine sua os proxime aemulatur, utpote candidum, rimosum & friabile: Si itaque intra terrae concavitates haec terra concavitatis rotundae locum invenerit, nascetur pila rotunda, quae discussa calvariam proxime aemulatur; si matrix fuerit disposita sub forma faemoris humani, aut costae, aut alterius membri, marga in ea contenta superaffuso salenitroso liquore, foemus humanum minus, majus, maximum & prorsus giganteum; pro matricis magnitudine exprimet. Atque haec sunt ossa ista, quae natura producit, & passim ossa gigantum communi hominum persuasione dicuntur, quae tamensi confregeris, nulla in eis nec medulla, nec medullae fistulosus meatus reperitur, quod fieri deberet, si hominum ossa forent.[7]

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[6] _Ibid._

[7] _Ibid._, Bk. VIII, Sect. ii, Ch. 4, p. 61: I say, deep within the earth, in the caverns of rocky mountains, there is a sort of slimy earth, which both I and Agricola have called marl. This marl, mixed with a kind of parget, encounters a nitrous solution in niches in the mountains, and becomes covered with a shell composed of parget. This shell petrifies with age, and acquires a luster from the

Kircher was not satisfied to conclude his treatment of these animal-like remains with this explanation, for he felt the necessity to provide an answer to the question: "Why did nature produce such figures?" His solution was a combination of the chance operations of natural forces and of the creativeness of the human imagination. Kircher noted, for example, that humans looking at clouds in the air or at spit on the ground often read into what they saw a great variety of things, such as winged dragons, cities, castles, and other things. Similarly, when gazing at mountains, they observed such things as human faces, tables, and reclining men.[8] Therefore, it was not unreasonable to suppose that the same process occurred in the observation of images upon stones, which began by the generation of a flow of saline liquid upon and into the cracks of a soft, earthy material. The pattern of rivers, trees, birds, and even humans appeared. Yet all this was only because a dried liquid had been formed in a mold, for hardly ever

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niter which causes it to resemble a bone both in whiteness, in porosity, and in brittleness. This white earth, if it finds a round cavity in the ground, produces a round ball which, if broken sufficiently, resembles a skull. If the mold has a form similar to a human or animal thighbone, or to a rib, or to any other bone, it will resemble that bone, because of the combination of marl and nitrous liquor. These false bones will depend in size upon the extent of the mold in which they are cast. These are the false bones which Nature produces, and which are called the bones of giants by common people. If they are broken, however, one finds no medullary substance in them, which one should, if they were either animal or human bones.

[8] Ibid., Sect. i, Ch. 9, p. 37.

were one of the images found perfect. Hands lacked fingers, heads eyes, and legs feet, all of which deficiencies were remedied by the artistic eye.[9]

Kircher investigated all these varied productions of nature, and his book was replete with numerous illustrations. For example, he had figured all of the letters of the Greek and Latin alphabets and all of the groups of simple figures from Euclid's Elements of Geometry, which he had discovered engraved upon a type of blue stone, lying in a field near Tolfens.[10] Kircher observed dendrites, or stones which were impressed with the likenesses of flowers, trees, and shrubs.[11] He also saw Apollo, Moses, crowns, crosses, numbers, coins, and many other objects figured upon stones, which suggested that his own imagination was as vivid as anybody else's.[12]

It was significant that Kircher's book was reviewed. In the same year that his work was published, the first two of the scientific journals appeared, that is, in order of release, the French Journal des Sçavans and the Philosophical Transactions of the Royal Society of London. Both journals contained notices and brief descriptions

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[9] Ibid., Ch. 10, pp. 40-41.

[10] Ibid., Ch. 8, p. 23.

[11] Ibid., Ch. 9, 32; Ch. 10, pp. 42-43; Sect. iii, Ch. 7, p. 84; Sect. iv, Ch. 1, p. 88.

[12] Ibid., Sect. i, Ch. 9, pp. 27-45.

of Kircher's work.[13]

An important new feature had thus been inserted into the fossil controversy, for a number of articles concerning fossils as well as notices about new books on fossils were to appear throughout the remainder of this century. The most important of the journals in this work was the Philosophical Transactions. Neither the French Journal nor the Mémoires of the French Academy, published later, or even the German Acta Eruditorum, which was first published in 1682 in Leipzig, could compare favorably in any manner with the English journal upon the subject of fossils. All three of these latter publications were primarily book review journals, especially the German one, and often the reviews were no more than a short notice of publication. They gave no picture, as did the English one, of the struggle between opposing theories upon this question. Consequently, the book reviews and articles in the Philosophical Transactions assumed, both because of their value and also because of the failure of rival journals, a major prominence.

From its inception, the Philosophical Transactions contained articles about fossils. Thomas Sprat (1636-1713),

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[13] [Anon.], "Mundus Subterraneus," Le Journal Des Sçavans, I (Juin 28, 1666), 299-305. See also [Anon.], "Of the Mundus Subterraneus of Athanasius Kircher," Philosophical Transactions: Giving Some Accompt of the Present Undertakings, Studies and Labours. Of the Ingenious in Many Considerable Parts of the World, I, No. 6 (November 6, 1665), 109-117. Cited hereafter as Philosophical Transactions.

who was appointed to write the first official history of the Royal Society, remarked, for example, that the Royal Society was eager to give information and assistance to investigators in matters concerning natural phenomena, and it made numerous inquiries in order to provoke responses about these matters.[14]

The accounts that they received from their members and from others made them feel justified in their efforts. In the area of fossils, for example, they took notice of relations about petrified teeth, and a petrified human foetus; experiments on fossil wood; and a paper about mussels living inside of rocks, which were found at Leghorn.[15] More significant articles were to be published later, many of which were of importance to the study of fossils.

At first, however, the contributions to the _Philosophical Transactions_ were not very scientific, and consisted primarily of relations of strange petrifications, of stones found within animals,[16] and of petrifying waters. For example, there were accounts of a huge stone rid at a

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[14]Thomas Sprat, _The History of the Royal-Society of London: For the Improving of Natural Knowledge_ (London: Printed by T.R. for J. Martyn, 1667), pp. 194-95.

[15]_Ibid._, p. 197.

[16]The generation of stones in animals and humans was then thought similar by many to the generation of these stones in the earth. See Francis C. Haber, _The Age of the World, Moses to Darwin_ (Baltimore: The Johns Hopkins Press, 1959), p. 43.

calf's birth;[17] of how wood was changed into stone at a place in England without petrifying water; of the healing power for poisons of a stone taken from a snake's head in Java;[19] of observables concerning petrification;[20] of a part of a tree sent to the Royal Society that was petrified without water;[21] of the search for a snake in the East Indies which contained within it a healing stone for poison;[22] of ninety-six stones removed from a person's bladder;[23] of a petrified snake found in the stomach of a

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[17] [Anon.], "An Account of A Very Odd Monstrous Calf," Philosophical Transactions, I, No. 1 (March 6, 1665), 10.

[18] [Anon.], "Of A Place in England, Where, without Petrifying Water, Wood Is Turned into Stone," Philosophical Transactions, I, No. 6 (November 6, 1665), 101-102.

[19] [Anon.], "Of the Nature of a Certain Stone, Found in the Indies, in the Head of a Serpent," Philosophical Transactions, I, No. 6 (November 6, 1665), 102-103.

[20] [Anon.], "Observables Touching Petrification," Philosophical Transactions, I, No. 18 (October 22, 1666), 320-21.

[21] Philip Packer, "An Addition to the Instances of Petrification, Enumerated in the Last Three of These Papers," Philosophical Transactions, I, No. 19 (November 19, 1666), 329-30.

[22] [Anon.], "Inquiries For Suratte, and Other Parts of the East Indies," Philosophical Transactions, II, No. 23 (March 11, 1667), 415-19.

[23] Nath. Fairfax , "Account of a Great Number of Stones, Found in One Bladder, By the Same," Philosophical Transactions, II, No. 26 (June 3, 1667), 482.

stag;[24] and of two partially petrified humans.[25]

At the same time, though, more promising articles were published, which included relations about Robert Hooke (1635-1703) looking at petrified wood and other bodies turned to stone which he had collected, through a microscope, and of how he drew what he had observed;[26] a review of Christopher Merret's (1614-1695) Pinax Rerum;[27] a notice of some observations sent from Italy by a Signior Manfredus Septalius (n.d.) of Milan, who reported that as he had passed by some mountains on his way to Genoa he was stopped by peasants, who had given him cockle shells, turbinets, echini, and pearl shells, which they had dug from the sides of a hill and which he had kept and placed in his repository;[28] and a mention of a query sent to a

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[24] [Anon.], "An Accompt of Two Books," Philosophical Transactions, V, No. 68 (February 20, 1670), 2077-82.

[25] Christoph. Kirby, "A Narrative of Two Petrifications in Humane Bodies, Communicated by Mr. Christoph. Kirby in a Letter from Dantzick, Dated April 18. 1671," Philosophical Transactions, VI, No. 71 (May 22, 1671), 2158-59.

[26] Robert Hooke , "An Account of Micrographia, or the Physiological Description of Minute Bodies, Made by Magnifying Glasses," Philosophical Transactions, I, No. 2 (April 3, 1665), 27-32.

[27] [Anon.] , "An Account of Some Books Lately Published," Philosophical Transactions, I, No. 20 (December 17, 1666), 364-67.

[28] Manfredus Septalius, "Some Observations Communicated by Signior Manfredus Septalius from Milan, Concerning Quicksilver Found at the Roots of Plants, and Shels Found

Dr. William Jackson (n.d.), asking him if any shells had been found lately near salt springs, and, if so, to comment about the earth around these springs.[29] The expectations aroused by these accounts for an article of importance in the study of fossils were fulfilled after six years.

This article was prompted by a thorough and lengthy review in 1671 of the English translation by Henry Oldenburg of the Prodromus of Nicolaus Steno.[30] In this review, it was noted that Steno had affirmed that he had resolved the problem of why substances that had the shapes of marine animals were found so far from the sea, and that he had answered the question of the place and manner of production of any body dug from the ground, of whatever figure, to such a certainty, that no school of philosophers could honestly challenge his conclusions.[31] Next, mention was made that Steno had used sea shells as examples for both assertions.[32] Examination showed why they were of so many

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upon In-land Mountains," Philosophical Transactions, II, No. 27 (September, 1667), 493.

[29]William Jackson, "Some Enquiries Concerning the Salt-Springs and the Way of Salt-making at Nantwhich in Chesire; Answered by the Learned and Observing William Jackson Dr. of Physick," Philosophical Transactions, IV, No. 53 (November 15, 1669), 1060-67.

[30][Anon.], "The Prodromus of a Dissertation Concerning a Solid Contained in a Solid, by Nicolaus Steno. English't out of Latin," Philosophical Transactions, VI, No. 72 (June 19, 1671), 2186-90.

[31]Ibid., 2186.

[32]Ibid., 2187-88.

colors and varieties, and that they were the remains of marine animals.[33] They also revealed the terrestrial and oceanic animal origin of other remains, such as different types of fish, skulls, horns, and teeth.[34] The article concluded with a remark that Steno had considered all the animal and vegetable remains that he had discussed to be the deposits of the universal deluge.[35]

Dr. Martin Lister (1638-1712) read both the review and Steno's book with interest, and soon wrote a letter, to be published in the Philosophical Transactions, in reply to each.[36] Lister, who at this time had not received his M.D. degree, was a practitioner of medicine and a student of animal life.[37] He was very interested in animal- and plant-like remains which he had examined, and at an early date had formulated definite ideas about them. He shortly became an authority on petrified shells in England, and was a disciple of the theory which held that shells and other excavated objects which had the forms of once-living

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[33] Ibid., 2189. [34] Ibid.

[35] Ibid., 2190.

[36] Martin Lister, "A Letter of Mr. Martin Lister, Written at York August 25 1671. Confirming the Observation in N°74 about Musk Sented Insected; Adding Some Notes upon D. Swammerdam's Book of Insects, and on that of M. Steno Concerning Petrify'd Shells," Philosophical Transactions, VI, No. 76 (October 22, 1671), 2281-84.

[37] Leslie Stephen and Sidney Lee (eds.), "Martin Lister," The Dictionary of National Biography (22 vols.; 2d reprinting; London: Oxford University Press, 1937-38), XI, 1229-30. Hereafter cited as DNB.

creatures were products of forces at work within the earth, or _lapides sui generis_. Lister exerted influence upon men such as John Ray and Edward Lhwyd (1660-1709), and this article against Steno was only the first of many contributions to the _Philosophical Transactions_ that he was to make on behalf of his own views.

Lister began with an enumeration of the problems to be solved. These were: first, the great variety and number of sea shells found far from the sea, imbedded within rocks or earth;[38] second, the apparent animal origin of these stony substances;[39] and, third, the relation of the stony shells of one place to those of another, or else to living shells.[40]

The first and second problems were considered jointly by Lister. He granted that a great variety in number and kind of sea shells were found not only around the shores of seas, but also in inland English quarries. He refused, however, to concede that these were once living sea shells, which later had become imbedded within the earth, and that had been petrified by any penetrating force of juices, that had replaced the rotted soft inner parts of the supposed animals. His position was that these shell-like stones were always _lapides sui generis_, or the result of forces at work within the earth, and that even

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[38] Lister, p. 2282. [39] _Ibid._

[40] _Ibid._, p. 2283.

Steno had recognized this.[41] Lister noted, as evidence of this assertion, that the shells which he had examined had no parts different in texture from the rock or quarry from which they were taken--iron-stone shells were all iron; marble shells all marble; lime shells all lime; crystalline shells all crystalline; and spar shells all spar. None had any parts that were animal remains.[42]

Furthermore, these shell-like stones had no relation either to each other, or to any living animal. Lister's reason for this was

> That Quarries of different stone yield us quite different sorts or species of shells, not only from one another (as those Cockle-stones of the Iron-stone Quarries of _Adderton_ in _York=shire_ differ from those found in the Lead=mines of the neighbouring mountains, and both these from that Cockle-Quarrie of _Wansford_- to be found in the Quarries about _Gunthrop_ and _Beavour_-Castle, & c;) but, I dare boldly say, from any thing in nature besides, that either the land, salt, or fresh water doth yield us. 'Tis true, that I have picked out of the one Quarry of _Wansford_ very resemblances of _Murices_, _Telinae_, _Turbines_, _Cochleae_, & c. and yet I am not convinced, when I particularly examined some of our English shores for shells, also the fresh waters and the fields, that I never did meet with any one of those _species_ of shells any where else, but in their respective Quarries, whence I conclude them _Lapides sui generis_, and that they were not cast in any _Animal mold_, whose species or race is yet to be found in being at this present day.[43]

Lister realized that his arguments might not sway those with different ideas, but he believed that anyone who made a careful study of the various species of these

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[41] _Ibid._, p. 2282.

[42] _Ibid._, pp. 2282-83.

[43] _Ibid._, p. 2283.

shell-like rocks, and who had not merely contented themselves with general examinations of stones in such vague areas as figures, resemblances, kinds, and others, would soon change their opinions to his own.[44] He concluded by remarking that those interested in these questions could consult the collection of shell-like stones at the Repository of the Royal Society, to which he himself would soon send some different types of Cockle-stones from different Quarries.[45]

Another book on fossils to be reviewed in the *Philosophical Transactions* in 1671 was Fridericus Lachmund's (1635-1676) *Oryctographia Hildesheimensis*.[46] Lachmund, a physician, described many of the fossils and other varieties of Hildesheim in his book, and illustrated it with a number of woodcuts. In the third section, or book, of his work, he discussed different types of stones, including dendrites, *orontia*, *ceraunia*, *aetites* (eagle-stones), *cornu ammonis*, trochites, and various kinds of petrified shells.[47] Lachmund was not certain about the origin of what he considered to be formed stones, and hence he cited as probable causes either the *succus lapidescens* of Agricola or the

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[44] *Ibid.* [45] *Ibid.*

[46] Fridericus Lachmund, *ΟΡΥΚΤΟΓΡΑΦΙΑ Hildesheimensis, sive admirandorum fossilium, qvae in tractu Hildesheimensi reperiuntur, descriptio iconibus illustrata, cui addita sunt alia de calculis, de fontibus, & c.* (Hildesheimii: Typis viduae Jacobi Mülleri, 1669).

[47] *Ibid.*, pp. 29, 21, 15, 22, 33, 52, 67.

spiritus plasticus of Kircher.[48]

Other contemporaries interested in fossils were Gabriel Plattes (fl. 1638), Jean Baptiste du Hamel (1624-1706), Bernhard Varen (1622-1650), and John Webster (1610-1682). Plattes believed in the existence of subterranean petrifying vapors, which had the power to turn earth into stones of various form, and he described a chemical experiment by which one could repeat this process.[49] Plattes also believed in the Flood of Noah and that the sea had once covered the land, but he did not say whether either event had deposited figured stones.[50] Da Hamel thought there was a lapific spirit, or succus lapidescens. This spirit was a rocky matter which was suspended in water, and it formed stone objects by its precipitation from the water.[51] Varen included several accounts of petrifying

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[48]Ibid., pp. 61-62.

[49] Gabriel Plattes , A Discovery of Subterranean Treasure, viz. of All Manner of Mines and Minerals, from the Gold to the Coal; with Plain Directions and Rules for the Finding of Them in All Kingdoms and Countries. And Also the Art of Melting, Refining, and Assaying of Them Is Plainly Declared So That Every Man That Is Indifferently Capacious May with Small Charge Presently Try the Value of Such Oares As Shall Be Found Either by Rule or by Accident. Also a Perfect Way to Try What Colour Any Berry, Leaf, Flower, Stalk, Root, Fruit, Seed, Bark, or Wood Will Give; with a Perfect Way to Make Colours that They Shall Not Stain, nor Fade Like Ordinary Colours (London: Printed for J.E. and are to be sold by Humphrey Moseley, 1653), pp. 5-7.

[50]Ibid., p. 7.

[51]Jean Baptiste du Hamel, Joan. Bapt. du Hamel De meteoris et fossilibus libri duo. In priore libro mixta

waters.[52] He described how saline waters effected this petrification process.[53] He believed that mountains were constantly arising from the sea, because, for example, vast quantities of sea shells were found in Gederland and other places.[54] Shells were even found ninety-five feet deep in Amsterdam, by workmen digging a well.[55]

John Webster's Metallographia (1671) began with a bibliographical essay on sources, and a proposal to find if and how metals grow.[56] This he did not do; he did summon authorities on the subject of metals, and included a large section on petrification.[57]

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imperfecta, quaeque in sublimi aere vel gignuntur, vel apparent, fuse pertractantur. Posterior liber mixta perfecta complectitur; ubi salium, bituminum, lapidum, gemmarum, & metallorum naturae, causae, & usus inquiruntur (Parisiis: Apud Petrum Lamy, 1660), pp. 185, 195.

[52]Bernhard Varen, Geographia generalis, in qua affectiones generalis telluris explicantur (Amstelodami: Ex Officina Elzeviriana, 1664), pp. 380-81.

[53]Ibid., pp. 381-83. [54]Ibid., pp. 131-32.

[55]Ibid., p. 98.

[56]John Webster, Metallographia: Or, an History of Metals Wherein Is Declared That the Signs of Ores and Minerals Both Before and After Digging, the Causes and Manner of Their Generations with the Description of Sundry New Metals, or Semi-Metals, and Many Other Things Pertaining to Mineral Knowledge. As Also, the Handling and Shewing of Their Vegetability, and the Discussion of the Most Difficult Questions Belonging to Mystical Chymistry, as of the Philosophers Gold, Their Mercury, the Liquor Alkahest, Auram Potabile, and Such Like Gathered Forth of the Most Approved Authors That Have Written in Greek, Latine, or High-Dutch; With Some Observations and Discoveries of the Author Himself (London: Printed by A.C. for Walter Kettilby, 1671), pp. 29-31, 33, 37-39.

[57]Ibid., pp. 358-72.

This addition was also in great part a review of authorities,[58] but it did contain a thorough explanation of the process of turning living things into stone, an explanation that embodied the thinking of many natural philosophers in this era upon this subject. As Webster, comparing petrification to the transmutation of metals, wrote:

> And in this the Transmutation of Metals, and of changing Wood, Moss, Leaves, Animals, Iron, and the like, into Stone, doth agree that they both have a substrate, or subject matter to work upon, and so the one not to be wondered at more than the other: but there are two properties wherein they differ.
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> 1. For first, in the petrification by Nature, the things changed are not always contained under the same proxime _genus_, and the thing working the effect of stonifying is of a Lapideous or Mineral nature, and (according to common opinion) neither contained within the Animal nor Vegetable Kingdom, and yet are wrought upon by that petrifying agent. . . .
>
> 2. Secondly, the things wrought by the petrifying agent, are more remote from that stony nature into which they are changed, whether they be Animals or Vegetables, as having had no praevious Preparation, to fit them for the susception of the Operation of that petrifying power. . . .
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> 3. Secondly, and as the agent in the change wrought is (according to the doctrine of _Helmont_) a petrific seed, consisting only in a saxeous odour, or invisible ferment; . . .[59]

These beliefs--that a petrific agent from the mineral Kingdom invaded the other two domains of nature, and turned them into mineral substances, and that the agent itself was either an odor or an invisible ferment from a petrific seed--were standard at this time. Common as well

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[58] _Ibid._, pp. 359-64. [59] _Ibid._, pp. 364-65.

was the characterization of these powers as mysterious--mysterious in the sense of the inability of natural philosophers to explain them by other than tautological methods.

This bewilderment led to the acceptance of stories such as Webster's relation of a tale from Helmont. It began with Webster declaring that the petrification process worked slowly by degrees. Nevertheless, he wrote, it also worked rapidly, as instanced by the sudden petrification of a whole tribe in Russia, including their wagons, horses, and cattle.[60]

Articles also appeared about fossils. One was on rock plants by John Beaumont (d. 1731).[61] Beaumont had investigated certain stones which had the shapes of living plants, and had found on them certain features, such as the hollows, rays, radii; and other things, which he considered of great importance for his belief in and discussion of their vegetation.[62] Beaumont also thought, as did Lister, that these stones were sports of nature and used them as arguments in favor of this position.[63]

Beaumont, using spar as an example, explained that

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[60] Ibid., p. 370.

[61] John Beaumont, "Two Letters Written by Mr. John Beaumont Junior of Stony-Easton in Somersetshire, Concerning Rock-Plants and Their Growth," Philosophical Transactions, XI, No. 129 (November 20, 1676).

[62] Ibid., pp. 725-732. [63] Ibid., p. 732.

the vegetation of stones took three forms: first, the formation of being from steams alone; second, the coagulation of steams with either dew or water; and, third, their growth from earths and clays.[64]

The stones of the Mendip Hills, according to Beaumont, originated in the third manner. Beginning with fine clay (usually white) of a smooth, soft texture, the stones grew to have ridges, knots, and sutures, and acquired a stony or sparry nature on the outside. Internally, the pith continued to be soft and white, and only gradually took on a stony character, which was brought about by a constant flow of mineral steams and moisture through the five hollow feet in the figured roots.[65]

It therefore could not be denied, according to Beaumont, that spar and stone plants, and fossil shells as well, grew by a process analogous to that of vegetables. He wrote:

> Nor can it be said but those stone-plants have true life and growth; for since in the curiosity of their make they may contend with the greatest part of the Vegetable Kingdom, having parts to assimulate nourishment by attraction, retention, concotion, and expulsion, I know not why they may not be allow'd as proper a vegetation as any plant, whatsoever. And indeed whatever has been said hitherto against the vegetation of Stones, to prove that they receive their increase only by <u>juxta-position</u>, has been chiefly meant of Common stones, which have no parts that carry any analogy with plants; whereas these are shap'd like them, having inward pith or sap, and likewise joynts, and runnings in their gut, and sometimes cell, which may well supply

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[64] *Ibid.*, pp. 734-35. [65] *Ibid.*, p. 737.

> the place of veins and fibres. . . .
> As to that opinion which generally solves these various Phaenomena of the several figur'd Stones, which we find in Mines and elsewhere, by saying that they are Parts of Plants and Animals, or whole ones, petrified, it seems to me not to be grounded on practical Knowledge. Thus when we find several sorts of Shell-fish in Mines, as there are some in the clay where those Stone-plants grow, we must not flie to petrifaction, as though they had been brought there by the Sea, or otherwise, and so petrified; but we must take that to be (as it is truly) the natural place of their birth; some of them being raw clay, others of the same texture with the Rock where they grow, and other of as absolute a shelly substance as any in the Sea; these being only different gradations of Nature, which can as well produce shells in Mines as in the Sea, there being no want of Saline nor Earthy particles.[66]

Many other such growths of stones existed in nature. Two were the Fungi Marini and the Coral. The former consisted of a sparry substance and had surfaces that were covered with flowers. These flowers, as Coral, were actually only terminations of sparry cells. Coral itself was a type of spar and some varieties had, as Ray had observed, joints.[67]

Opponents who believed that these stones were the remains of plants or animals had no basis for their opinions, because there were a number of convincing arguments against them. Martin Lister, for instance, had written that shells from different quarries were of a different species from both each other and from any living shells, whether they were of land or of aquatic origin.[68] Beaumont himself had

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[66] Ibid., pp. 737-38. [67] Ibid., p. 738.

[68] Ibid.

gathered many kinds of shells from both quarries and plowed fields, and had compared them with shells in extant collections. None matched.[69]

Another argument was the very number of stones found, for which petrification could not possibly account. The process of turning objects into stone itself often involved no more than a mere stony incrustation. Moreover, Beaumont had never observed petrification in action, and the only evidences which he had seen of this process were objects already supposedly petrified.[70]

The argument Beaumont considered most important, however, was the obstinacy of those who refused to recognize that these formed stones were anything else but the remains of plants and animals. They denied the power of nature to express the shapes of plants and animals without vegetative life, and they neglected to see the workings of that same nature around them. They did not observe the patterns made by snow, the landscapes carved upon rocks, and the figures of ferns and animals wrought upon coal.[71]

The power of nature to which Beaumont referred took the form, in the instance of figured stones, in a seminal root, since he would accept neither petrifaction nor the vegetative soul of the Aristotelians.[72] This root, or seed, operated when an unlikely locale forbade the operation

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[69] Ibid.

[70] Ibid., pp. 738-39.

[71] Ibid., p. 739.

[72] Ibid.

of the principle of life which God used to first generate animals and plants, and which now spontaneously functioned.

It was difficult to explain what the root was. Many ancients, according to Beaumont, thought that it was an outward mover which made figures for an unknown reason. The Peripatetics, he noted, believed the seed had an implanted virtue, which sometimes had an analagous nature with the seed.[73] Beaumont himself thought that this root was an agent, which was most strongly active in the presence of the chief principles of nature-salts, sulphurs, and mercuries, and in the most advantageous places--beds of clays and marls, and in coal mines. Great numbers of figured stones found there confirmed this supposition.[74] For example, salts in marchasite clays produced snakes and shells; sulphurs in coal mines made herbs; and mercuries in ore mines wrought herbs.[75] He believed that these figures were impossible to explain mechanically,[76] and that only a seminal principle would do.

The writings of Beaumont were significant for those who believed that figured stones were non-organic productions of nature. He had explained their vegetation from a mineral viewpoint; he had collected and examined many such stones for use as examples; and he had set forth a number of plausible arguments against those who felt that

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[73] Ibid.

[74] Ibid., p. 740.

[75] Ibid.

[76] Ibid., pp. 740-41.

these were organic productions.

This latter concern of Beaumont indicated a struggle between two groups of thinkers, those who thought fossils organic productions of nature, and those who believed them inorganic. The conflict was more pronounced in Robert Plot's (1640-1696) Natural History of Oxfordshire (1677), published the year after Beaumont's article had been made public.

Plot was a propertied gentleman who devoted his leisure to antiquarian interests. The first "custos" of the Ashmolean Museum at Oxford, he became secretary to the Royal Society, and an editor of the Philosophical Transactions.[77] Plot believed that formed stones were the result of the combination of a plastic virtue and a petrifying influence at work within the earth, an outlook which caused him to be described as ". . . one of the last champions of the old views in England."[78] His major contribution to the fossil controversy was the Natural History of Oxford-shire, a work that was notable not so much for the author's concepts of fossils, but rather for its numerous illustrations, frequent citations of authorities, and immense amounts of

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[77] Leslie Stephen and Sidney Lee (eds.), "Robert Plot," DNB, XV, 1310-12.

[78] H. Harnshaw Thomas, "The Rise of Geology and Its Influence on Contemporary Thought," Annals of Science, A Quarterly Review of the History of Science Since the Renaissance, V, No. 4 (July 15, 1947), 327. Hereafter cited as AS.

detail, the latter of which was characteristic of his antiquarianism.[79]

Plot was very concerned with the compilation of data to support his ideas. In his section on petrifying waters, for instance, he devoted two pages to a description of a waterfall at Sommerton, which had petrifying powers.[80] This description served as an introduction to a discussion of the action of such waters. Plot thought that all petrifying waters sprang from salts. These salts, sublimed and rarified in the bowels of the earth into an invisible steam, mixed with common waters,[81] producing particles of various sizes. The larger and grosser ones incrusted the outside of the object to be petrified, while the smaller and finer ones insinuated themselves into the pores of the object. The result was a slow but thorough petrification, which could be confirmed by a chemical analysis.[82] This would reveal that all indurated products consisted of an earthy and a sulphuric mixture, and were highly saturated with the saline principle.[83]

The production of formed stones considered, Plot

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[79] J. Challinor, "The Early Progress of British Geology, I., From Leland to Woodward, 1538-1728," AS, IX, No. 2 (June 30, 1953), p. 132.

[80] R[obert] P[lot], The Natural History of Oxfordshire, Being an Essay Toward the Natural History of England (Oxford: Printed at the Theater, 1677), pp. 31-36.

[81] Ibid., p. 32.

[82] Ibid.

[83] Ibid.

then arranged them into categories according to that which they resembled, or for which they were named. These groups were those that related to the heavenly bodies, or air; to the aquatic kingdom; to the plants and animals; and to art objects.[84] Each group was discussed, and many of the seventy plates were devoted to these subjects.[85]

One of these discussions concerned stones which were similar in shape to fish. Plot said that these stones were of such variety that it seemed impossible to call them anything else save the petrified remains of real fish, so that great care was necessary to explain their true formation.[86] First, many were examined that had been collected either personally by Plot or else that had been sent to him by his many correspondents. Their locations, description, and references to them by authorities were noted.[87] Then their origin was determined. Here Plot agreed with Martin Lister (whom he cited) and concluded that since they were so unlike any shell fish now living, they were therefore always lapides sui generis, and never any part of a living shell, which had died and then had been transmuted by petrifying juices.[88] As usual, Plot referred to many examples of shell fish for support, one of which was a huge

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[84] Ibid., p. 80. [85] Ibid.

[86] Ibid., p. 98. [87] Ibid., pp. 98-111.

[88] Ibid., pp. 102-103.

nautilus-like shell, mentioned in Christopher Merrett's (1614-1695) Pinax, which far exceeded in width and in number of turns, that of any living nautili.[89]

Plot was not, however, satisfied that this was the only answer for the origin of these stones. He had stated the opinion he preferred, but he admitted that this was a vexatious question for natural philosophers. This . . .

> . . . brings me to consider the great Question now so much controverted in the World. Whether the stones we find in the forms of shell-fish, be Lapides sui generis, naturally produced by some extraordinary plastic virtue latent in the earth or Quarries where they are found? Or whether they rather owe their form and figuration to the shells of the Fishes they represents brought to the places where they are now found by a Deluge, Earth-quake, or some other such means, and there being filled with mud, clay, and petrifying juices, have in the tract of time been turned into stones, as we now find them, still retaining the same shape in the whole, with the same lineations, sutures, eminences, cavities, orifices, points that they had whil'st they were shells?[90]

The replies left philosophers divided. Plot took the former view, standing ". . . rather to the opinion of Mr. Lister, that they are Lapides, . . .," while Robert Hooke, John Ray, and Nicolaus Steno, as Plot remarked, held the latter opinion.[91]

Plot considered his opponents' position to have more insuperable difficulties than his. First, they had to allow the existence of a flood to bear the shells inland,

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[89] Ibid., pp. 110-11. [90] Ibid., p. 111.

[91] Ibid., pp. 111-12.

which was either the Deluge of Noah or else a more local flood, such as the Ogygean or Deucalion Floods in Greece.[92] Nothing was more improbable. Noah's Deluge was almost certainly limited in scope, and even if it was universal, Ray had observed that in the case of either rains or an eruption of the fountains of the Deep, shell fish would have been drawn away from the surface and would have clung to the depths of the ocean to weather the storm.[93] Moreover, granting that shells were brought by the Flood, they would have been scattered over hills and valleys, but instead they were found clustered in like groups at the bases of hills.[94] Finally, Noah's Flood was too short and too violent to drive shells so far and to disperse them into breeding colonies.[95]

Secondly, shells were not brought by any national flood, of which two were recorded in Greece. Even if there was an unrecorded flood that covered England, lasting hundreds of years, it is difficult to see how the waters could have carried the heavy shells to the summits of mountains. Unrecorded earthquakes would have been required for this task.[96]

Plot rejected the assumption of such upheavals in primitive times because of evidence gathered from the

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[92]*Ibid.*, p. 112. [93]*Ibid.* [94]*Ibid.*, pp. 112-13.

[95]*Ibid.*, p. 113. [96]*Ibid.*, pp. 113-14.

examination of the shell-like evidence, which strongly suggested that they were lapides sui generis. The major conclusions that Plot derived were first, that some of the shells found had shapes like those of living shell fish that always were found clinging to rocks. It would have required a violent flood to have moved shell and rock both.[97]

Second, many shell bones that must have been deposited by a flood, if there were one, were not discovered by Plot. There were no whale or sea horse bones, and no bones of squammeous fish, such as shells of Buccina, Murices, Conchae Veneris, and Solenes. There were few bones of crustaceous fish, such as crabs and lobsters, which have locomotion and could have ascended hills. Only testaceous-like shells were encountered.[98]

Third, many shell-like stones, such as bivalves, were found which resembled no living species of shell fish. It was unlikely that any such shells were part of a species that was now lost out of the world. The Creator, who took great care to preserve all the species at the time of Noah's Flood, would hardly have allowed any one species to have been so lost.[99]

Fourth, there were many formed stones that had forms like no body, either of plants or animals, in whole or in part. Examples were belemnites, astroites, and selenites.

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[97] Ibid. [98] Ibid., p. 114. [99] Ibid., pp. 114-15.

If these were granted to have been produced by a plastic power, why not the others? Plant- and animal-like stones were no more difficult to form. Some, however, even attributed these three to be animal remains. The astroites, for example, were called the tail-bones of petrified fish, since they resembled the assembled vertebrae of a particular fish. If they were correct, then why were not the tail-bones of other fish found?[100]

Fifth, there were those shells which had shapes so like those of living shell fish, such as oysters and cockles, that there could be no exception made because of their shape, so that they really might once have been shells. These were found in many places with one shell, and not the other. Were they really once living shell fish, they would have almost surely had both shells.[101]

Sixth, similar kinds of formed stones could not have been molded in living shells, since they were now scattered about in some instances, and gathered in beds in others. Nor could bivalvular-like stones have been so different. Some, such as the ostracites and pectinites, were always found with their shells open; others, such as the conchites, always with their shells closed.[102]

Seventh and last, many of the formed stones seemed to have been created where they found, as the selenites

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[100] Ibid.   [101] Ibid., p. 117.   [102] Ibid.

at Shot-over and the Conchites at Cornwell. Moreover, Plot found at the latter place a small cockle made of stone within a larger one made of clay; if they had been formed inside cockle shells, both would have been made entirely of either stone or clay. Nor were they each brought by separate floods, since they were in the same bed, and one within the other.

Another piece of evidence that these stones had been generated where they were now found was submitted by John Ray. It concerned a cockle shell that was stone-like, found in the belly of a beef, where it, according to Ray, surely was bred and grew into that figure.[103]

Plot realized that there were objections to his conclusions, and he noted ones raised by Robert Hooke, Nicolaus Steno, and Paolo Boccone.[104] Hooke remarked, for example, that among the so-called formed stones were some which were so like living shells in figure, color, and substance, that they could have been nothing else but the remains of shells which were formerly alive.[105] Hooke also reasoned that nature would not have wasted her time in the useless creation of such stones.[106]

To both objections Plot offered lengthy replies. For the first, Plot noted, with Martin Lister, that many

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[103]*Ibid.*, pp. 117-18.

[104]*Ibid.*, p. 118.

[105]*Ibid.*

[106]*Ibid.*, p. 120.

former shells were found far inland. Some were thrown up on the sea shores; others farther inland were remnants of shell fish eaten and discarded by the inhabitants of towns, or, as in the case of the town of Reading, were the leavings of a beseiging army. These shells had been permeated by petrifying juices and had been either wholly or partially petrified with the passage of time.[107]

Plot did not, however, agree that all the formed stones that had shapes similar to living shell fish were the remains of animals. He considered this argument drawn from similitudes to be weak, because to him there were many things in nature that appeared to be the same, especially among the formed stones. The Auriculare and Cardite stones perfectly resembled those parts of men from which they took their names, yet no one would have suggested that they actually had been parts of men that were now petrified.[108]

The second objection was for Plot not an objection at all. Nature no more created figured stones for foolish reasons, than it did when it made flowers. Both flowers and figured stones beautified the world with the varieties of their productions. Many of the latter had medicinal uses as well.[109]

Plot summarized his position in great detail. He

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[107] Ibid., pp. 119-20. [108] Ibid., p. 120.

[109] Ibid., p. 121.

described the workings of the salt principle in the creative plastic virtue.[110] He arranged formed stones by that which they had forms similar to--animal, vegetable, and man, buttressing this division with extensive citations of authorities.[111] Finally, he discussed various unusual aspects of formed stones and those remains which he considered to be relics of past ages, such as the discovery of the bones of giants, and the collection of stones which appeared to be human productions.[112]

Plot was not original, but he did represent the ideas of those who believed that fossils were non-organic productions of nature. He reviewed numerous authorities, and complimented this with a number of excellent illustrations. He presented arguments against those who held that fossils were not formed stones. Plot's work was a reference to all those who speculated upon the origin of fossils, whether they supported him or not.

Another believer in the non-organic origin of fossils was Martin Lister. Lister was a correspondent to whom many were sending collected specimens and their ideas about them; he was an author, and he was the final arbiter in many instances as to what position a writer would espouse.[113]

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[110]<u>Ibid.</u>, pp. 121-24. [111]<u>Ibid.</u>, pp. 124-32.

[112]<u>Ibid.</u>, pp. 121-42.

[113]See John Ray, <u>Observations Topographical, Moral, & Physiological; Made in a Journey through Part of the</u>

Lister contributed a number of articles to the Philosophical Transactions in the 1670's on the subject of fossils. Included among these were an account of stones which were figured like plants;[114] a letter on snails and stone-like shells;[115] and a relation of a rock figured as an iris and of glossopetrae, or stones resembling sharks' teeth, which were taken from English quarries.[116]

In addition, Lister wrote a book, Historiae Animalium Angliae (1678),[117] in which he reiterated his conception that formed stones were lapides sui generis, or one with the rock itself, because different kinds of rock yielded

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Low-Countries, Germany, Italy, and France: With a Catalogue of Plants Not Native of England, Found Spontaneously Growing in Those Parts, and Their Virtues (London: Printed for John Martyn, 1673), p. 5-6 .

[114]Martin Lister, "A Description of Certain Stones Figured Like Plants, and by Some Observing Men Esteemed To Be Plants Petrified," Philosophical Transactions, VIII, No. 100 (February 9, 1673), pp. 6181-91.

[115]_______, "An Extract of a Letter of Mr. Martin Lister Concerning the First Part of His Tables of Snails, Together with Some Quaere's Relating to Those Insects, and the Tables Themselves," Philosophical Transactions, IX, No. 105 (July 20, 1674), 96-97.

[116]_______, "Some Observations and Experiments Made, and in a Letter Communicated to the Publisher, for the Royal Society," Philosophical Transactions, IX, No. 110 (January 25, 1675), 221-26.

[117]_______, Historiae animalium Angliae tres tractatus unus de araneis. Alter de cochleis. Tum terrestribus tum fluviatilibus. Tertius de cochleis marinis. Quibus adjectus est quartus de lapidibus ejusdem insulae ad cochlearum quandam imaginem figuratis: Memoriae & rationi (Londini: Apud Joh. Martyn, 1678).

different kinds of formed stones, different from each other and from any kind living today. Lister, as he had indicated in previous articles, accepted some of these shells as organic remains, while the bulk he considered to have non-organic beginnings.[118] This work also had a great number of plates, with written descriptions thereof, in the sections on shells. The illustrations made the work valuable for later reference purposes.

Besides books, there were many articles about fossils in this time. The articles covered four general areas--accounts of books on fossils; the study of mineralizing and petrifying forces in nature; the description of various types of fossils; and the discovery of widespread fossil phenomena. Of the first, there was a notice of the translation of Alvaro Barba's Arte de los Metales by the Earl of Sandwich (n.d.).[119] Filippo Buonanni's (1638-1725) Ricreatio dell'occhio e della Mente (1681) received an unfavorable review.[120] Robert Sibbald's (1641-1722) Scotia Illustrata (1684) got a brief account,[121] and James

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[118] Ibid., A_2 recto-(:)verso, A_3 recto-(:)verso.

[119] [Anon.], "The First Book of the Art of Mettals, Written in Spanish by Alonso Barba, & c., and English't by the R.H. Edward Earl of Sandwich. London, 1674," Philosophical Transactions, IX, No. 108 (November 23, 1674), 187-191.

[120] [Anon.], "An Account of a Book Intitled Ricreatione dell'occhio e della Mente Nell'osservation 'delle Chiccole Dal P. Filippo Buomanni & c. in Roma, per il Varese, 1681," Philosophical Transactions, XIV, No. 156 (February 20, 1684), 507-509.

[121] [Anon.], "Scotia illustrata, sive Prodromus

Petiver's (1663?-1718) Musei Petiveriani (1696) had a lengthy relation and critique.[122]

Second, contributions on the study of mineralizing and petrifying forces were usually descriptive rather than explanatory. There was one article upon petrifying waters[123] and two by Frederick Slare (n.d.) upon the production of stones in the bladder, processes for which contemporaries saw many parallels.[124] Daniel Coxe (n.d.) entered an

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historiae naturalis, & c.," Philosophical Transactions, XIV, No. 165 (November 20, 1684), 795-98.

[122] [Anon.], "An Account of a Book Musei petiveriani centuria prima carisia naturae continens: viz. animalia, fossilia, plantas, ex variis mundi plagis advecta, ordine digesta, nominibus propius signata & iconibus aeneis eleganter illustrata," Philosophical Transactions, XIX, No. 224 (January, 1697), 393-400.

[123] James Gregory, "Extracts of Several Letters Sent to the Publisher from Edinburg, by the Learn'd Mr. James Gregory, to Whom They Were Written by That Intelligent Knight Sir George Makenzy from Tarbut," Philosophical Transactions, X, No. 114 (May 24, 1675), 307-308. See also J. Beal, "Advertisements, Occasioned by the Remarks Printed in Numb. 114, Upon Frost in Some Parts of Scotland, Differing in Their Anniversary Seasons and Force from Our Ordinary Frosts in England: Of Black Winds and Tempests: Of the Warm or Fertilizing Temperature and Steams of the Surface of the Earth, Stones, Rocks, Springs, Waters (Some in Some Places, More than in Other Places;) Of Petrifying and Metallizing Waters: With Some Hints for the Horti-culture of Scotland," Philosophical Transactions, X, No. 116 (July 26, 1675), 357-67.

[124] Frederick Slare, "An Abstract of a Treatise of the Calculus Humanus in Answer to Several Queries Proposed by Sir John Hoskins," Philosophical Transactions, XIV, No. 157 (March 20, 1684), 523-33. See also _______, "A Short Examen of the Stones Sent to the R. Society from Berne, Whereof an Account Is Given in the Last Transaction," Philosophical Transactions, XVI, No. 182 (June 26, 1686), 140-45.

experiment that he thought explained the figures of trees, shrubs, and other such growths upon rocks. He burned one fern and collected the salts from its ashes. After resuscitation, or treatment of the salts with urinous spirits and equal parts of salt armoniac and ashes, the resulting product formed representations of firs, pines, and another type of tree.[125] William Molyneux (n.d.), secretary to the Society of Dublin, discussed the petrifying qualities of Lough Neagh in Ireland,[126] and received a reply from an Edward Smyth (n.d.), which questioned the validity of all his statements of facts and posed queries, which were unanswered, to him.[127]

Third, while philosophers pursued their debate about the cause of formed stones, new accounts of various kinds of such stones continued to be published. These included

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[125]Daniel Coxe, "A Continuation of Dr. Daniel Coxe's Discourse, Begun in Numb. 107. Touching the Identity of All Volatil Salts, and Vinous Spirits; Together with Two Surprizing Experiments Concerning Vegetable Salts, Perfectly Resembling the Shape of the Plants, Whence They Had Been Obtained," Philosophical Transactions, IX, No. 108 (November 23, 1674), 169-78.

[126]William Molyneux, "A Letter from the Learned and Ingenious Mr Will Molyneux Secretary to the Society of Dublin, to Will. Musgrave L.L.B. Fellow of New Colledge, and Secretary to the Philosophical Society of Oxford, for Advancement of Natural Knowledge, Concerning Lough Neagh in Ireland, and Its Petrifying Qualities," Philosophical Transactions, XIV, No. 158 (April 20, 1684), 552-54.

[127]Edward Smyth, "An Answer to Some Quaeries Proposed by Mr. William Molyneux, Concerning Lough-Neagh," Philosophical Transactions, XV, No. 174 (August 22, 1685), 1108-12.

a description of bezoar stones--thought to have medicinal value, and shaped as buttons--growing inside goats and cows;[128] a further relation by John Beaumont about rock-like plants growing in the Mendip Hills,[129] which he considered lapides sui generis;[130] and an account of the great numbers of types of formed stones to be found on the Giants' Causeway in Northern Ireland.[131]

Fourth, another concurrent development was being carried on over a vast area by investigators who were often literally unearthing new fossil phenomena. Griff Hatley (n.d.) found a bed of shells in Kent.[132] John Clayton (n.d.) observed several miles of interspersed oyster shell beds in Virginia.[133] Robert Sibbald sent to Martin

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[128] [Anon.], "More Observations of Monsieur Taverniers Voyages; Promised in the Next Foregoing Tract," Philosophical Transactions, XI, No. 130 (December 14, 1676), 751-58.

[129] John Beaumont, "A Further Account of Some Rock-plants Growing in the Lead Mines of Mendip-Hills, Mention'd in the Philosophical Transactions, Numb. 129. by the Ingenious Mr. John Beaumont Jun. of Stony-Easton in Sommerset Shire," Philosophical Transactions, XIII, No. 150 (August 10, 1683), 276-79.

[130] Ibid., 277.

[131] Thomas Molyneux, "Some Notes upon the Foregoing Account of the Giant's Causeway, Serving to Further Illustrate the Same," Philosophical Transactions, XVIII, No. 212 (For the months of July and August, 1694), 175-82.

[132] Griff. Hatley, "A Letter Concerning Some Form'd Stones Found at Hunton in Kent," Philosophical Transactions, XIV, No. 155 (January 20, 1684), 463-65.

[133] John Clayton, "A Continuation of Mr. John

Lister a letter describing the shells he was gathering in Scotland.[134] Hans Sloane (1660-1753) wrote an extensive account about fossil finds in Jamaica and Maryland.[135] James Cuninghame (n.d.) collected shells on Ascencion Island and arranged them in a catalogue.[136] James Brewer (n.d.) wrote about oyster shell beds in Barkshire.[137] Abr[aham] de la Pryme (1672-1704) gathered shells from two stone quarries in Lincolnshire.[138] Other collectors and places of collection were James Wallace (n.d.) in the

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Clayton's Account of Virginia," Philosophical Transactions, XVII, No. 205 (For the Month of November, 1693), 941-48.

[134]Robert Sibbald, "A Letter from Sir Robert Sibbald to Dr. Martin Lister Coll. Med. Lond. & S.R.S. Containing An Account of Several Shells Observed by Him in Scotland," Philosophical Transactions, XIX, No. 222 (For the Months of September and October, 1696), 321-25.

[135]Hans Sloane, "An Account of the Tongue of a Pastinaca Marina, Frequent in the Seas about Jamaica, and Lately Dug Up in Maryland, and England," Philosophical Transactions, XIX, No. 232 (For the Month of September, 1697), 674-76.

[136]James Cuninghame, "A Catalogue of Shells, & c. Gathered At the Island of Ascention, By Mr. James Cuninghame Chirurgeon, With What Plants He There Observed," Philosophical Transactions, XXI, No. 255 (For the Month of August, 1699), 295-300.

[137]James Brewer, "Part of Two Letters From Dr. James Brewer to Dr. Sloane, Concerning Beds of Oyster-shells Found Near Reading in Barkshire," Philosophical Transactions, XXII, No. 261 (For the Month of February, 1700), [484]-86.

[138]Abr[aham] de la Pryme, "A Letter of the Reverend Mr. Abr. de la Pryme to the Publisher, Concerning Broughton in Lincolnshire; With His Observations on the Shell-fish Observed in the Quarries About That Place," Philosophical Transactions, XXII, No. 266 (For the Months of September and October, 1700), 677-87.

Orkney Islands;[139] Sibbald, again in Scotland;[140] Stephen Gray (d. 1736), renowned in electricity, at Reculver Cliff;[141] Samuel Brown (n.d.) in the Moluccas;[142] and James Fraser (n.d.) on a mountain near Lake Ness.[143]

This fourth phase of activity concerning fossils was marked by the many collectors who believed that the fossils which they were collecting were organic productions of nature. Several of the early contributors who expressed opinions on this subject mentioned Lister and agreed with his opinions. Such were Hatley[144] and

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139 [Anon.], "An Abstract of a Book, Viz. An Account of the Islands of Orkney. By James Wallace, M.D. and Fellow of the Royal Society. To Which Is Added, an Essay Concerning the Thule of the Ancients," Philosophical Transactions, XXII, No. 262 (For the Month of March, 1700), 543-46.

140 Robert Sibbald, "Part of a Letter From Sir Robert Sibbald, to the Publisher, Giving An Account of Some Stones and Plants Found Lately in Scotland, and of Some Books Now Printing There," Philosophical Transactions, XXII, No. 266 (For the Months of September and October, 1700), 693-94.

141 Stephen Gray, "Part of a Letter from Mr. Stephen Gray to the Publisher, Containing His Observations on the Fossils of Reculver Cliffe, and a New Way of Drawing the Meridian Line, With a Note on This Letter by the Publisher," Philosophical Transactions, XXII, No. 268 (For the Month of January, 1700), 762-64.

142 James Petiver, "A Description of Some Shells Found on the Molucca Islands; As Also an Account of Mr. Sam. Brown, His Fourth Book of East India Plants, With Their Names, Vertues, & c.," Philosophical Transactions, XXII, No. 274 (For the Month of September, 1701), 927-33.

143 James Fraser, "Part of a Letter Wrote by Mr. James Fraser, Minister of Kirkhil, Near Ivernes, to Ja. Wallace at Edinburgh, Concerning the Lake Ness, & c., Philosophical Transactions, XXI, No. 254 (For the Month of July, 1699), 230-32.

144 Hatley, 463-64.

Sibbald.[145] Clayton concurred with these latter two, but did not note Lister.[146]

Others did not agree with Lister. As Hans Sloane wrote:

> Dr. Tancred Robinson, Fellow of the College of Physicians and Royal Society, did me the favor some time since; to show me a considerable number of Fossil Bones and Shells of several sorts he had lately come to his hands from Mary-land. Some of them had received little alteration in the Earth; others more, and some were changed as to be stony, but all of them retain'd their ancient shape so well, that it was easie for any body, who remembred the Figures of the parts of these Animals, to conclude these Fossils must have come from the same Original.[147]

Sloane had perceived a connection between fossil remains and living organisms, and had attempted to support this by a comparison of a fish tongue taken from a live fish from Jamaica with two fossil fish tongues, one excavated in Maryland, and the other from a collection. He did so to his own satisfaction.[148]

This connection was seen by others, also, and the concern became, to such men as Brewer[149] and Fraser,[150] not that fossils were organic remains, but that what were they

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[145] Sibbald, "Sibbald to Lister," 321.

[146] Clayton, 942.

[147] Sloane, 674.

[148] *Ibid.*, 674-75.

[149] Brewer, 484.

[150] Fraser, 232.

doing so far from the sea? De la Pryme said that they were remains deposited by the Deluge of Noah,[151] and Gray agreed with that solution.[152]

Regardless of the answers given to this secondary question, many now saw fossils in a new way. Many observers were not content, with Lister, to call fossils lapides sui generis, and thus at once explain both their origin and location. They were confronted by an influx of new empirical evidence and found that the previously accepted theories were now aesthetically unsatisfactory to contend with it. They saw no other choice but to adopt a different view. Thus they adopted another opinion and accepted the organic origin of fossils.

Their view was reflected in books as well as in articles. The books included ones by Philip Jacob Hartmann (1648-1717),[153] Filippo Buonanni,[154] Robert Sibbald,[155]

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[151]De la Pryme, 678.

[152]Gray, 763.

[153]Philip Jacob Hartmann, Succini Prussici Physica & Civilis Historia (Regiomonti: apud Martinum Hallervord Bibliopol, 1677).

[154]Filippo Buonanni, Ricreatione dell 'occhio e della mente, nell ' osseruation' delle Chiocciole, proporta a' curiosi delle opere della natura dal P. Filippo Buonanni della compagnia di giesv. Con quattrocento, e cinquanta figure di testacei diuersi, sopra cui si spiegano molti curiosi problemi (Roma: il Varese, 1684).

[155]Robert Sibbald, Scotia illustrata, sive prodromus historiae nautralis in quo regionis natura, incolarum ingenia & mores, morbi iisque medendi methodus, & medicina

and Thomas Pope Blount (1649-1697).[156]

Hartmann considered amber, which he believed was the product of underground forces in operation.[157] He found several substances within this amber, some of which had shapes like dead creatures, such as gnats. These, he thought, were also products of subterranean forces.[158] Hartmann noted that amber was found all over Prussia, usually with sand. He concluded that the inland amber and sand were from the sea. They were brought to their position not by a universal deluge, but by subterranean water passages from the sea.[159] This latter conclusion was contradictory, unless amber was produced under both land and sea.

Buonanni wrote about shell fish in his book. He divided them, according to the number and figure of their

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indigena accurate explicantur: et multiplices naturae partus in triplice ejus regno, vegetabili scilicet, animali & minerali per hancce borealem magnae britaniae partem, quae antiquissimum scotiae regnum constituit, undiquaque diffusi nunc primum in lucem eruuntur, & varii eorum usus, medici praesertim & mechanici, quos ad vitae cum necessitatem, tum commoditatem praestant, cunctis perspicue exponuntur (Edinburgi: Ex officina typographica Jacobi Kniblo, Josuae Solingensis, & Johannis Colmarii, 1684).

[156]Thomas Pope Blount, A Natural History: Containing Many Not Common Observations: Extracted Out of the Best Modern Writers (London: Printed for R. Bentley, 1693).

[157]Hartmann, Bk. II, Ch. 7, p. 194.

[158]Ibid., Ch. 5, pp. 84-85.

[159]Ibid., Ch. I, pp. 35-36, Ch. III, p. 57.

shells, into the categories of univalves, bivalves, and turbinated shells.[160] He discussed their origin, also, and rejected the reasoning of everyone upon this subject, including Steno and Lister,[161] and excepting only Aristotle, whose opinion he supported, namely, that the shell-like formed stones were produced by underground vapors.[162] He concluded with reviews of various famous collections of shell fish, such as that of Wormius at Amsterdam and Aldrovandi at Bologna,[163] and by adding descriptions and illustrations of hundreds of plates.

Robert Sibbald included within a large work a section on the history of fossils in Scotland, entitled <u>Prodromi Naturalis Historiae Scotiae</u>. Sibbald had no original ideas concerning fossils, and he patterned his opinions after Martin Lister's, holding that fossils were <u>lapides sui generis</u>.[164] He did give a great number of descriptions, and occasionally cited authorities for these. He included a number of plates at the close of his work, among which were figured a dendrite and a marine-like fossil.

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[160] Buonanni, p. [iv].

[161] <u>Ibid</u>., pp. 39-41.

[162] <u>Ibid</u>., pp. 28-30, 38-39, 41-42.

[163] <u>Ibid</u>., pp. 125-32.

[164] Sibbald, <u>Prodromus</u>, Pt. II, Bk. 4, pp. 48-49, 55.

Thomas Pope Blount discussed petrifying waters. His ideas about them were not novel. Some of them were embodied, for example, in his descriptions of the operation of the saline principle in petrification, of the petrifying steams in action, and of the chemical tests for petrified objects.[165] Blount also believed that formed stones were *lapides sui generis*.[166]

Edward Lhwyd wrote the *Lithophylacii Britannici*.[167] Lhwyd, the second keeper of the Ashmolean Museum, succeeded Plot in this post in 1691. An authority both upon antiquities and upon fossils, Lhwyd had been a student of Plot's at Oxford.[168] Lhwyd did not agree with his teacher about the origin of fossils. Neither did he agree with either proponents of the Noachian Deluge or of *lusus naturae*.

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[165]Blount, pp. 195-98.

[166]*Ibid.*, p. 198.

[167]Edward Lhwyd, *Edvardi Luidi apud oxonienses cimeliarchae ashmoleani lithophylacii britannici. Sive lapidum aliorumque fossilium britannicorum singulari figura insignium, quotquot hactenus vel ipse invenit ab amicis accepit, distributio classica: scrinii sui lapidarii repertorium cum locis singulorum natalibus exhibens. Additis rariorum aliquot figuris aere incisis*; *cum epistolis ad clarissimos viros de quibusdam circa marina fossilia & stirpes minerales praesertim notandis* (Editio altera, novis quorundam speciminum iconibus aucta. Subjicitur authoris praelectio de stellis marinis & c.; Oxonii: E typographeo clarendoniano, 1760).

[168]Leslie Stephen and Sidney Lee, "Edward Lhwyd," *DNB*, XI, 1096-98. Lhwyd's alliance of interests was not unusual. See Cecil Schneer, "The Rise of Historical Geology in the Seventeenth Century," *Isis*, XLV, Part 3, No. 131 (September, 1954), 256-68.

Lhwyd was, instead, an advocate of the spermatic principle, or aura seminalis, a belief perhaps connected with the animalculist school.

Lhwyd presented and defended his theory in one of the letters appended to his book.[169] His spermatic principle was apparently heavily dependent upon animalculist bases. The animalculists believed that the male sperm contained a tiny complete animal, and that the role of the female was to nourish this being. Another agent, however, competed for the female's role--the earth. If the earth contained some sort of nutrient, such as a saline moisture, then there was no reason why animal semen, insinuated into one of its pores, should not grow and develop, and become fossils.

Lhwyd delayed the argument of this theory, for the press of other developments forced his attention. Many now believed that fossils were organic remains which had been

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[169]Though his book was published long after his death, the letter was well known to contemporaries, and was available in 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 (The Third Edition; London: Printed for William Innys, 1713), pp. 175-203.

deposited at the Deluge, while others held the ideas of Plot and others which stated that fossils were formed by nature acting through the plastic power of salts.[170] Lhwyd found it necessary to refute both concepts, especially the former, before he pursued his own.[171]

Lhwyd began his attack on the diluvialists with a division of their position into marine bodies and mineral plants, and offered separate but closely connected arguments against each. Neither, he said, were deposited by the Deluge.

Marine fossils, in particular, were not diluvial remains. A flood would have scattered them about the surface of the earth, and not left them lodged deeply. Yet they were found enclosed throughout masses of solid marble on the broken faces of sea cliffs, some of which cliffs were more than two hundred fathoms above the water. They were in other substances and locations as well--in lime cliffs in Pembrokeshire, Wales, Ireland, and other countries. It was inconceivable, Lhwyd thought, even with a vast amount of time, to imagine the force necessary to push bodies so far down into clay and earth.[172]

Moreover, marine fossils were found in caves. Lhwyd himself had gathered there specimens of Entrochi, and had

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[170] Lhwyd, p. 131. [171] _Ibid._, pp. 131-32.

[172] _Ibid._, p. 132.

observed remains of cockles. These remains were embedded in the sides of the caves, and often encrusted over with stalagmites, where water would scarcely have left them.[173]

Lhwyd went on to cite other factors in opposition to the deposition of marine fossils by the Deluge. Bones, horns, and hoofs of land animals were seldom, if at all, found inside of stone, indicating that the supposed Deluge had left no land spoils.[174] Some of the presumed shells left by the waters were composed, as Steno admitted (said Lhwyd), entirely of spar crystal, which was an unbelievable alteration to occur to their composition, while their form remained the same.[175] Other shells contained living animals, such as the lobster found in Italy inside marble, the cockles in Zetland, and the mussels in Flintshire, all of which were not descendants of survivors of the Deluge, for no empty shells were left behind.[176] Further, the same kind of shells found in the same quarry, as Steno confessed (again Lhwyd said), must have undergone the same changes, but this was not so; testaceous shells frequently were discovered adhering to crystalline shells.[177] In addition, there were too many shells, fossil teeth, and other remains of all kinds for the Deluge to possibly account for.[178] Of these remains,

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[173]Ibid., pp. 132-33. [174]Ibid., p. 133.

[175]Ibid. [176]Ibid., pp. 133-34.

[177]Ibid. [178]Ibid., p. 134.

Lhwyd thought that many were only superficial representatives of marine animals, because it was difficult for him to imagine, for example, how only the outline of fish vertebrae could have survived upon marchasite, while all the vertebrae themselves had disappeared.[179] Other of these remains were as nothing that anyone had seen living; Lhwyd himself possessed over forty varieties of Cornu Ammonis shells, and Woodward and others had more kinds, which implied that since these shells had no connection with living ocean fish (ignoring the impossible possibility of species extinction), they were scarcely relics of the Deluge.[180] Finally, Lhwyd noted that marine-like substances were often generated in human bodies, as Dr. Lister and others had attested. Certainly these shells were not of diluvial origin; and, Lhwyd insinuated in favor of his own theory, it was far less amazing that these bodies should have been produced within the earth, than in the bodies of men and animals.[181]

Lhwyd's arguments against what he called mineral plants--fossil leaves and branches--were approximately the same as those against marine fossils. He did not see how they could have been deposited so deeply and in slate coal and other hard bodies.[182] He saw no representatives among fossil leaves of leaves of living vegetation, nor any

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[179] Ibid., pp. 134-35.

[180] Ibid., p. 135.

[181] Ibid.

[182] Ibid.

remains of trees similar to existing trees. He observed many differences between fossil leaves and living leaves. Lastly, fossil leaves were smaller than that which they had the shapes of, and were nothing more than mere outlines of living plants, rather than impressions in stones.[183]

The theory that fossils were formed by some force at work within the earth was also dismissed by Lhwyd. He argued that no one had given a satisfactory account of the causes and methods operative in those productions, and the plastic power of Dr. Plot's salts, if used as a recourse, were subject to an objection. That was, that no reason could be given why these salts could represent objects composed of different substances. The salts, for instance, had a form like both the teeth of the glossopetra, or dog-fish, and their roots, which were parts of the jaw.[184]

Lhwyd, having refuted both concepts, presented his own. He imagined that fossils were the growths of living seeds. Fish spawn, for example, carried from the sea by exhalations, came down upon the earth with rains and fogs. They were then deposited by the falling waters within matrices inside of the earth, where they matured. Other growths of fossils, such as leaves and branches, were also the result of a similar process. This production of fossils was possible because of the minuteness of the seeds of living beings, which made it easy to transport

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[183] Ibid., pp. 135-36. [184] Ibid., p. 136.

these seeds into small places. Moreover, since the seeds of all creatures were so tiny, this production could also account for all of the many types of fossils that had been found.[185]

Lhwyd believed that all the fossils dug from the earth were tracible to natural bodies whose seeds had been exposed to either air or water, that is, to plants, insects, and fish. Animals were excluded, and their exclusion was confirmed experientially; no skeletons, horns, hoofs, or feathers were found.[186]

The production of these fossils was a continuing process. New fossils were constantly being produced, and old ones were decaying. This was demonstrated by the repeated finds of both old fossils that were losing their shape and of many entire ones.[187]

The acceptance of this production according to his theory, Lhwyd wrote, explained two otherwise mysterious occurrences. One was the presence of fossil nautili, and other strange shells. The seeds of these, by the theory, could have been taken up by clouds from far-away lands and rained down upon England. The other was the existence of great numbers of shells of many varieties. It appeared far easier, to Lhwyd, to account for their apparent vegetative

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[185] _Ibid._, pp. 136-37. [186] _Ibid._, p. 137.

[187] _Ibid._, pp. 137-38.

growth, by his theory.[188]

Lhwyd proudly noted that there were other phenomena that his aura seminalis explained better than did the diluvial theory. These included the great depth of plant leaves; the large quantity of marine bodies; the wide variety of unknown shells in a small England; the frequency of distortion and unevenness of the surface of the bodies; the even distribution of the bodies through all the depths of the land; and the discovery of shells in the roofs of caves, on the sides of cliffs, and in living animals.[189]

Lhwyd realized, despite his pretensions, that his theory would incur opposition. Therefore, he set out to anticipate it by drawing up and then answering a list of criticisms.

To Lhwyd, and to historical retrospect, one target was his exclusion of animals and birds from the ranks of fossil remains. About that time many large bones were being excavated, which some observers, such as Thomas Molyneux (n.d.), considered to be animal bones.[190] Lhwyd denied their conclusions for several reasons. First, he

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[188] Ibid., pp. 138-39. [189] Ibid., p. 139.

[190] Thomas Molyneux, "A Discourse Concerning the Large Horns, Frequently Found Under Ground in Ireland. Concluding from Them That the Great American Deer, Call'd a Moose, Was Formerly Common in That Island: With Remarks on Some Other Things Natural to That Country," Philosophical Transactions, XIX, No. 227 (For the Month of April, 1697), 489-512.

held, they were in error, because they said that they had seen figures after polishing. Polishing defaced, not restored, figures. Second, observers were too eager to ascribe to land animals characteristics of fossils which, upon closer inspection, would have been seen to have been those of marine bodies. Last, although it was true that bones, horns, and hoofs were sometimes excavated, they were so few that it seemed best to attribute their burial to accidents, because all land animals had perished in the Deluge, and their remains had decayed. Lhwyd concluded with the notation that, if a competent author showed him delineations of viviparous animals in rocks, then he would discard his hypothesis.[191]

There were other difficulties for Lhwyd to consider. His theory presented many implausibilities: the <u>Seminum</u> in the earth penetrated the pores of the stones; the fossil bodies were similarly located in different kinds of rocks in all countries; most shells were found apart, and not adhering to each other, as living ones did; fossil shells of the same kind were found ranged in size from nearly invisible to fully grown; the parts of the spawn, even when taken out of the water and separated, still achieved their form within the earth; the marine-like bodies were only representations, and not once-living, despite the

[191]Lhwyd, pp. 138-39.

discoveries of tracks of shells, of pearls sticking to the shells, of the change of color near the roots of some fossil fish teeth, and of the worn extremities of others, indicating that these teeth were once used in fish jaws; many fish teeth, particularly _glossopetrae_, came from viviparous fish, rendering it impossible to reproduce them by Lhwyd's theory; and, last, such a production as Lhwyd postulated seemed both mystical and unpurposeful.[192]

All these objections, according to Lhwyd, were answerable. First, experience (the root of solid philosophy) revealed that animal spawn insinuated itself into stone--live toads were found in rocks, and Pholades in seemingly unreachable matrices inside of stones.[193] Second, it was no more amazing to believe that spawn, aided by saline moisture, grew in rocks, than in the human body, which latter was a much more unfavorable environment.[194] Third, shells did grow in rocks, despite the smallness of the cavity where this growth began. The hardest stones, as experience again showed, yielded to such growth.[195] Fourth, it was not necessary for Lhwyd's hypothesis that all marine bodies should grow everywhere. Different soils forbade, as in the case of vegetables, similar productions.[196] Fifth, it was

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[192]_Ibid._, pp. 139-40.

[193]_Ibid._, p. 140.

[194]_Ibid._

[195]_Ibid._

[196]_Ibid._, pp. 140-41.

not strange that marine bodies were found much more abundantly in some places than in others. Their growth and decay was related to the nature of the minerals in which they were embedded; the longer the mineral lasted, the longer the fossil survived.[197] Sixth, fossils were found in vast ranges of magnitude. Some were very large; others, as Steno affirmed (Lhwyd declared), were so small that a microscope was almost required to see them.[198] Seventh, experience demonstrated that spawn could produce out of its natural place. There were accounts of growths both in the earth and in man and animals.[199] Eighth, the marine bodies were only representations, not real bodies. Signs, such as tracks or shells or indications that shells formerly stuck together, were accidents, perhaps caused by workmen digging, or by the sinking of the ground. The worn edges and the change of the color of the teeth of the Plectronitae were probably caused by natural processes that occurred in living species, of which science was ignorant. Lhwyd acknowledged, however, that these teeth and others like them might possibly have been diluvial remains.[200] Ninth, it was not necessarily true that dog-fish shells found beneath the surface of the earth were the spawn of viviparous animals.

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[197] Ibid., p. 141.

[198] Ibid.

[199] Ibid.

[200] Ibid.

Naturalists knew little about the generation of these cartilagineous fish. Lhwyd personally had observed some to be oviparous and others to be viviparous, and had seen embryos in a variety of dog-fish, which were cast upon the shore.[201] Tenth, and finally, Lhwyd believed that these marine fossils had some purpose in nature, as all of God's creations must. He speculated that this end might have been the fertilization of the earth; more shells were found in fertile countries than in barren ones.[202]

Lhwyd had taken great care to present his position, but he was willing to admit error in instance after instance. In this, he differed in approach to the explanation of natural phenomena from most philosophers, for despite his dogmatism, he confessed that his theory offered a possible, and not necessarily the only, solution. He thought that knowledge about fossils was chaotic and uncertain, but he looked forward to the ultimate determination of the truth: He noted that he had made many observations on fossils, but he remarked that the ideas that he had so carefully drawn from them on one day were thrown into doubt by those he saw on the next day. He concluded, however, that the great curiosities and discoveries of his age encouraged him to hope that a final determination of the fossil question would soon be found.[203]

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[201] Ibid., pp. 141-42. [202] Ibid.

[203] Ibid., p. 131.

He hoped that the true theory was his own.

Lhwyd was aware that he wrote in a period of great change, and consequently he addressed his remarks to what he considered to be the most powerful group in the study of fossils--the diluvial theorists who had opted for an organic origin of those bodies. Then one of the few proponents of the spermatic principle, Lhwyd did influence at least one writer who had diluvial leanings, John Ray. Nevertheless, Lhwyd failed to convince anyone of the validity of his hypothesis, despite his excellent presentation of it. Many natural philosophers simply did not accept any solution to the fossil controversy, save the diluvial one. Even Ray, regardless of his respect for Lhwyd, rejected the latter's spermatic principle.[204]

Perhaps Lhwyd failed because of an uncertainty in his own beliefs. He often admitted that his statements were only conjectures, subject to refutation,[205] and that in particular cases the theories of the diluvialists were as probable as his were.[206] Such an attitude was not conducive to success, and revealed that probably Lhwyd himself was attracted to the diluvial school.

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[204]Ray, pp. 203-204.

[205]An example was his discussion of the remains of land animals. See Lhwyd, pp. 137-38.

[206]One instance concerned Plectronitae teeth. See Lhwyd, p. 141.

This apparent attraction and semi-surrender of Lhwyd to the diluvialists was fatal, and undermined the basis of his whole argument, which was rooted in the non-organic origin of fossils. Those who believed in the Deluge had, in general, first accepted the organic beginnings of fossils, and then explained the location of these animal and plants remains with the medium of the flood waters. For Lhwyd to convince them otherwise, he could not allow the plausibility of their latter premise, because it was essential to the maintenance of their former one. Yet this is precisely what he did, and thus doomed his own aura seminalis. Once again, however, it was unlikely that a more rigid stand by Lhwyd would have caused his success, because the minds of his opponents were fixed.

Their minds were many. A number of writers who discoursed upon the subject of fossils compromised with the Deluge of Noah. Moreover, since they so closely connected the Deluge and the organic production of fossils, some authors who believed in the non-organic production of fossils abandoned their hypothesis.

One such writer was Charles Leigh (1662-1701), a naturalist and a Doctor of Physick. Leigh believed in a non-organic source of fossils, and he borrowed all his ideas on this topic from the writings of others. He was, because of a combination of his lack of originality and of his general conformity with what was then the fashionable scientific thinking among many, a remarkable indicator of the unfortunate position that those who believed that fossils were non-organic productions of nature had reached.

Leigh put his opinions into a book entitled The Natural History of Lancashire, Chesire, and the Peak in Derbyshire (1700).[207] In it, Leigh set forth, in the manner of a learned dilettante, an imposing welter of concepts, which he discussed in a pedantic rather than in a critical manner. He was favorable to most of the ideas then acceptable to the received accord of the natural philosophers, and unfavorable to the others.

In this mode, Leigh endorsed the universality of the Deluge of Noah. After he had mentioned that subterranean trees and other fossils had prompted a debate upon whether they were formed there, or else were brought there by the Flood, he remarked:

> Under these are found frequently the Exuviae of Animals as Shells, Bones of Fishes, under one particularly I saw the Head of the Hippopotomaus; it is plain from hence these could not come from any other cause but a Deluge, . . . Secondly, these Ranks of Trees found together nowise invalidates the Deluge, for the same Argument may be urged against fossile Shells, which are frequently found collected there; yet I suppose no Man will urge this as an Argument of their not being brought thither by a Deluge, but rather the contrary, since upon the Sea-shore in their native Beds they are always found in great Numbers.

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[207]Charles Leigh, The Natural History of Lancashire, Chesire, and the Peak, in Derbyshire: With an Account of the British, Phoenician, Armenian, Gr. and Rom. Antiquities in Those Parts (Oxford: Printed for the Author, 1700).

> To these may be added that remarkable Mountain called _Naphat_ in the Province of _Conought_ in the Kingdom of _Ireland_, which is several hundred Fathom above the surface of the Sea, yet at the top of this Mountain ten Yards within it are vast Beds of all sorts of Marine Shells, as _Whelks_, _Mussels_, _Cockles_, _Perewinkles_, _Torculars_, _Pectinites_, _Turbinites_, _Oysters_, & c. which doubtless, considering the immense height of the Mountain, could not be deposited there by any means but a Deluge, and that an universal one.[208]

Leigh also cited other evidences of the Deluge, such as the mountains of oyster shells in Virginia and a skeleton of a buck found in England.[209] The best support, though, was that of Holy Scripture. The Bible made it evident, he declared, that there was a universal deluge; the role of natural phenomena was merely to confirm the holy writ, and it did, to the careful observer of nature.[210]

Leigh was hostile, however, as were other observers, to John Woodward's (1665-1728) hypothesis concerning the Deluge. Woodward had postulated that the Deluge had been universal, and that gradually the waters had dissolved all the earthy matter. The waters next lessened, and matter began to settle downwards in relation to its specific gravity, the heavier objects forming the lower layers, the lighter ones the upper layers.

Leigh found Woodward's universal dissolution difficult to comprehend. He could not imagine how . . .

> . . . that in that general Destruction there should be such a _Menstruum_, or universal Dissolvent in Nature,

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[208]_Ibid._, Bk. I, 61-62. [209]_Ibid._, 62.

[210]_Ibid._, 100-101.

> that should convert all the Strata of the Earth, Mines, Minerals, and Metals into a liquid Form, and yet some few Shells, Bones, and Plants, remain undissolved, which are of a much softer texture, and as we find by repeated Experiments, far more easily to be detected?[211]

Despite his affirmation of what he thought were Scriptural revelations, Leigh did not totally abandon the non-organic production of fossils. He believed that there were two exceptions to the theory that organic remains were depositions of the Deluge. These exceptions were plants and formed stones.

Plants, Leigh wrote, could be made by chemical processes from various solutions.[212] The careful experimenter could, in a laboratory, induce saline, bituminous, and terrene particles to join together in such a fashion as to produce representations of various rocks, much in the same manner as snow formed patterns on window panes. Moreover, this same experimenter could check his results. He could reduce the rocks that contained these representations to their primary mixtures, and then conceivably return them back to their stony composition as a final test of confirmation.[213]

Formed stones also required special treatment. Bufonites, Belemnites, Ophites or Cornu Ammonis, and other fossils, such as living toads, all of which were found in

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[211] Ibid., 116-17.

[212] Ibid., 99.

[213] Ibid.

rocks, were attributed by Leigh to the action of the principle of ovism.[214] Toads, for example, were created by an *ovum* or egg, which was released into the air, and later came down to earth. Rain, or a spring, next picked up the egg and transported it into stone cavities in the earth. There the egg developed, and grew to maturity.[215]

There were many other instances of such generation and growth in nature, Leigh thought, and one of these was that of river eels:

> It may now be worth our time to make Enquiry into the manner of the Generation of this kind of Fish [eels]: I could not in these, by any Dissection I ever made, observe the distinction of Male and Female, which was given occasion to some to conjecture they came from the middle Region, since Ponds and Pits are frequently full of them in wch [sic] none had ever been deposited, and therefore 'tis concluded that their *Ova* being so small as not to be discerned by ocular Inspection, they might be exhal'd with the Waters, and consequently fall down with the Rains, and when these happen'd to fall into Rivers and Ponds, they by the influence of the Sun, begin and compleat their Generation.[216]

Leigh added that this hypothesis was confirmed by microscopical investigation; no penis, ova, or ovaria were found in eels.[217]

Leigh's book was somewhat comparable to the *Natural History* of Pliny, written centuries before. Leigh had tried to compose an encyclopedical work upon fossils, and did not restrict himself to any single opinion. He simultaneously

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[214] *Ibid.*, 119.

[215] *Ibid.*, 119-20.

[216] *Ibid.*, 143.

[217] *Ibid.*, 144.

was an ovist, a diluvialist, and a follower of Plot--all of which beliefs, taken together, were difficult to reconcile. He had compiled a large work with many plates and with many contradictions. He had cited many sources. In addition, he had both yielded to authority and yet had betrayed the influence of many then unacceptable philosophers.

Perhaps in all this Leigh was more representative of the writings of his time than were the more narrowly oriented contemporary scientists. His own resistance to categorization, marked principally by his belief both in the Deluge and in the non-organic production of formed stones, caused his book to divulge many of the speculations then about in the fossil controversy. His passivity to authority, epitomized in his acceptance of the diluvial deposition of shells and bones, marked what was approved on fossils among several scientific thinkers. Finally, his dependence upon a large amount of details and illustrations in the composition of his work was an indication of a trend among scholars which characterized a number of similar treatises.

The belief that fossils were non-organic productions of nature virtually ended with the efforts of Leigh. A summarization of its history in the latter half of the seventeenth century was as follows--in the early years, a strong beginning, based upon ancient roots; in the middle period, an apologetic defense, caused by an increased popularity among philosophers in the organic origin of fossils; and at the close, a weak compromise, initiated by a desparate attempt to salvage a dead concept.

The demise of this idea is difficult to explain. It is wrong to postulate that other ideas were better, or were easier to prove, or were more correct. They were no more any of these than the defunct one was. It is also incorrect to ascribe the fall of this concept to the work of a few brilliant men, such as Steno or Hooke. Lister and Lhwyd were about as able for the other side, and Plot gathered supporting evidence just as Ray did. Furthermore, a number of philosophers, when these fifty years under consideration are thought of as a whole, believed this particular idea.

What more probably happened to sabotage the faith in the inorganic production of fossils was the emergence in the latter part of the century of a new factor, hitherto latent, which was the Deluge. The Deluge, if one confided in it, made formed stones, celestial influences, plastic virtues, and all the other concepts of the inorganic group unnecessary. In place of these, the diluvialists found it much more convenient, despite certain conflicts, to substitute the *exuviae* of aquatic and land animals as labels for these still unknown stones, for which opposing philosophers had given previously equally plausible arguments. It was, after all, the duty of scientists to explain natural phenomena, and what better explanation could be afforded than one which so nicely coincided with an interest in Holy Scripture, and which so well agreed, in the minds of many scholars, with its literal teachings. Confronted with the more mentally satisfactory answer of an inseparability of the organic origin of fossils and of the Mosaic Deluge, the belief in the inorganic inception of fossils had to disappear.

CHAPTER III

FOSSILS AS ORGANIC PRODUCTIONS OF NATURE

The organic origin of fossils was an old idea which gradually came to prominence in the last half of the seventeenth century. Simply stated, it held that fossils which had the shapes of plants and animals were organic in origin. The natural philosophers of this time who believed in this idea used this apparent visual corroboration as a base for their arguments, much as had the ancient Greeks who had believed that the sun revolved about the earth, and that it did so because it was observable. Unfortunately for the latter-day observers, their conclusion was not as well accepted as that of the Greeks had been, and other arguments, which were no more convincing to opposing philosophers, were employed by them.

Despite both hindrances and early unacceptability, however, their position ultimately triumphed over that of those who believed in the inorganic source of fossils, and in this triumph their efforts gained, in historical retrospect, an increased significance. In the early years after 1650, though, this was not the situation. The

The emergence of these theorists' views to prominence was not easily explainable, for their ideas possessed no intrinsically better merits than did other ideas.

Nor were their arguments more easily provable than those of others, because science did not (and yet does not) operate upon principles that relied upon proofs. Historians often presented, as did Francis Haber (n.d.), the hypothesis that fossils were recognized as of organic origin because of the accumulation of a tremendous amount of data, and of the comparison of this data with living counterparts.[1] Scrutiny reveals otherwise; the collection of specimens and the illustration of books was no monopoly of any group of scholars, but rather was a part of a long historical trend. Martin Lister, for example, was renowned for his collection of fossils, and he was considered a foremost authority in regard to their locations and descriptions. With an absence, then, of a perspective of the theory of the organic origin of fossils established upon the inevitable progress of irrefutably tangible evidence, this theory may be seen as only one of a number of answers to the fossil enigma.

One of the first writers in this time to support this answer was Robert Hooke (1635-1703) in his book,

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[1]Francis C. Haber, The Age of the World, Moses to Darwin (Baltimore: The Johns Hopkins Press, 1959), p. 59.

Micrographia.[2] Hooke, a graduate of Oxford and a Secretary of the Royal Society,[3] initiated his studies about fossils with the aid of the microscope. He sliced and polished pieces of petrified wood and then examined them with the aid of his visual tool. Hooke compared the results he obtained with his microscopical examinations of other petrified substances, and especially with petrified shells.[4] He believed that his investigations revealed many resemblances between the wood and his other subjects.

Hooke extended his research to include a comparison between petrified objects and what he thought were their living counterparts. He found that petrified wood resembled living wood in shape, and in the arrangement of the grain and of the pores, and that the two differed in weight, hardness, closeness, incombustibility, indissolubility, rigidness and friability, and in touch and feeling.[5] He reasoned that these likenesses were because the petrified wood had once been living wood, and the differences were because the petrifying waters had subtly introduced

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[2]Robert Hooke, Micrographia: Or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses. With Observations and Inquiries Thereupon (London: Printed by Jo. Martyn and Ja. Allestry, 1665).

[3]Leslie Stephen and Sidney Lee (eds.), "Robert Hooke," The Dictionary of National Biography (22 vols., 2d reprinting; London: Oxford University Press, 1937-38), IX, 1177-81. Hereafter cited as DNB.

[4]Hooke, Micrographia, p. 107.

[5]Ibid., p. 108.

changes in the wood after it had died and rotted.[6]

The important step in these investigations by Hooke was his idea that a connection existed between the petrified objects and the living things, and it was not his use of the microscope. With such an idea, Hooke employed the microscope to confirm to his own satisfaction what he already believed. Others, confronted with the same evidence, concluded that there was no such link and that the resemblances were merely the results of the work of an imitative force in nature. Hooke did not, therefore, regardless of his use of an instrument, investigate with any more of an unbiased attitude than any other scientist.

Hooke's attitude in this regard was displayed in his further studies on petrification. He believed that other substances besides wood were altered by petrification, and that these objects were, as wood, once living things. The numbers and variety of these other petrifications were many, and included representatives from both the animal and vegetable kingdoms.[7]

The constitutions of these petrifications were of particular interest to Hooke. He noted that petrified shells, for example, were composed of materials which quite differed in hardness, such as clay and marl. They had a wide range in color and transparency; from white to

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[6] Ibid., p. 109. [7] Ibid.

black and from marble to crystal, respectively. They varied in the manner of their figuration; some appeared to have been the matter that filled the inside of a shell fish, and others the material that enveloped shell fish. They had all stages of outward coverings, from a shell perfect in figure, color, and matter, to mere fragments of shells, which adhered to pieces of petrified matter. All these findings were thought by Hooke to be inconclusive support for his theory.[8]

Hooke relied upon the microscope for his conclusive evidence. He confirmed naked-eye observation which indicated that the various lines which he had found across the surface of petrified shells were actually sutures, or the termini of diaphragms, which were tiny partitions that divided the cavities of the shells into regular cells. The material of these sutures was the same as the material of the outer shell, and was different from that of the matter which filled the cavities, indicating that the sutures were part of an originally living shell fish. The living matter in the cells had rotted away after the death of the shell fish, and had since been replaced by petrified matter.[9] Hooke believed this gave him his answer. As he wrote:

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[8] *Ibid.*, p. 110.

[9] *Ibid.*, pp. 110-11.

> From all which, and, several other particulars which I observ'd, I cannot but think, that all these, and most other kinds of strong bodies which are found thus strangely figured, do owe their formation and figuration, not to any kind of Plastick virtue inherent in the earth, but to the shells of certain shel-fishes, which, either by some Deluge, Inundation, Earthquake, or some such means, came to be thrown to that place, and there to be fill'd with some kind of Mudd or Clay, or petrifying Water, or some other substance, which in tract of time has been settled together in those shelly moulds into those shaped substances we now find them; . . .[10]

This conclusion led Hooke to explain several things. First, bruises, fragmentation, and other damage to shells resulted from the earthquake that brought them to where they were now deposited. Second, these shells represented many kinds of living shell fish, such as nautili, cockles, mussels, periwinkles, scallops, and others. Third, many of these shells were only impressions because the real shell long ago had decayed and had left behind the enclosed and enclosing petrified earth. Fourth, surviving shells were often petrified and had acquired a stony nature because of their long proximity to petrified substances. Fifth and finally, shells frequently contained many varieties of matter, as a result of having been filled in one place, and then having been carried to another. Some shells had undergone this change on as many as five occasions, as the different substances inside them illustrated.[11]

Hooke had presented his solution to the fossil

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[10] *Ibid.*, p. 111.

[11] *Ibid.*, pp. 111-12.

question. It was based, he believed, upon empirical evidence. He was not able to imagine, he wrote, how anybody could examine the shells and then propound a different answer than his.[12] Moreover, he thought that his solution could be extended, after proper study, to answer the question about the origin of other formed stones besides shells. He said that collectors should gather these stones, and make surveys of all the available information concerning them. A history of observations then could be compiled, and the true origin of these stones determined.[13]

Hooke had one final argument against those who held that these formed stones were the work of a sporting nature. It was that such formed stones had some other purpose than sport, though he did not know what this purpose was. He remarked that

> it has a long time been a general observation and maxime; that Nature does nothing in vain; It seems, I say, contrary to that great Wisdom of Nature, that these prettily shap'd bodies should have all those curious Figures and contrivances (which many of them are adorn'd and contriv'd with) generated or wrought by a Plastick virtue, for no higher end then onely to exhibit such a form; which he that shall thoroughly consider all the circumstances of such Kind of Figur'd bodies, will, I think, have enough reasons to believe, though I confess one cannot presently be able to find out what Nature's designs are.[14]

Hooke's statements were typical of those who believed that formed stones were of organic origin. He

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[12] Ibid., p. 112. [13] Ibid.

[14] Ibid.

used empirical evidence; the power of petrifying waters for the alteration of once-living things; the past violence of nature to account for the present location of marine fossils; and the negative argument that his opinion was more proper in God's scheme, and that the sport-of-nature view was contrary to nature, because it provided for the creation of formed stones to no purpose. His only innovation, the study of fossils through a microscope, had no lasting consequences.

Hooke continued his studies of fossils, of which the *Micrographia* constituted only a portent. Hooke was a careful investigator, and apparently was original. His later work was well-presented.

Other writers who held views similar to Hooke's were Christopher Merret (1614-1695) and Robert Boyle (1627-1691). Merret, a physician and a student of natural history,[15] attempted to survey all the flora, fauna, fossils, and other natural features of England in his book, *Pinax*.[16] He also tried in it to catalogue the fossils--or things dug from the ground. These fossils included metals and all sorts of stones, such as objects turned into stones, and stones extracted from animals,

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[15]Leslie Stephen and Sidney Lee (eds.), "Christopher Merret," *DNB*, XIII, 288-89.

[16]Christopher Merret, *Pinax rerum naturalium britannicarum, continens vegetabilia, animalia, et fossilia, in hac insula reperta inchoatus* (Londini: typis T. Roycroft, impensis Cave Pulleyn, 1667).

both of which he discussed.[17]

Of the stones extracted from animals and people, Merret considered, as did many contemporaries, that they had the same origins as those taken from the earth. He discussed stones from sheep bladders, noted that parts of the aorta petrified in old persons, and remarked that pearls occurred frequently in both oysters and mussels. He objected, however, to count toad-stones among these types of stones, because he wrote that he had demonstrated them before the King to be in reality the molar-teeth of wolf-fish.[18]

As for the objects turned into stone, Merret made a lengthy enumeration of them. He listed cockles, periwinkles, scallops, oysters, and mussels taken from Badminton in Gloucestershire, a bucardite sent to him by his eldest son Robert from Oxford; echinites of white color, cited by Aldrovandi; glossopetra, or a tongue stone, mentioned in Boodt; ophiomorphites, or snake-stones (cornu ammonis) found at Keimsham, Adderley, and Farnham in Surrey; stelechites of different forms, some of which were from Wales and which were sent to the museum of the Royal Society; stalagmites, or dropping stones, from the well at Knaresborough and from Buchan in Scotland; an echinoid presented by a Dr. Balle (n.d.); stones from Tradescant's

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[17] Merret, Pinax, pp. 209-19.

[18] Ibid., pp. 210-11.

Museum; a stone which resembled a cat's tail from Holy Island; and an egg-shaped stone from Worcestershire.[19] Merret also mentioned stones from the sea.[20]

Of all these petrified stones, Merret chose the one sent by Dr. Balle to use in order to present his views on the organic nature of fossils. Merret believed that many formed stones were of organic origin, and had petrified with the passage of time. As he wrote after his description of Balle's stones:

> . . . unde & ex aliis quamplurimis liquido mihi constat multos lapides pro naturalibus habitos ex animalibus eorumve partibus mediante ... succo quodam terrestri effictos, vel haec figuram suam communicasse ... argillae vel terrae cuivis molli, & postea periisse servata figura, ut in lapidibus Islebianis liquido patet, in quibus sedulo observatori squammae occurrunt manifestae.[21]

Merret's work represented a somewhat halting effort to identify stones which resembled plants and animals as organic remains, and it presented a large, though unillustrated, collection of such remains. However, Merret made no attempt to separate formed stones from any others, except by a nominal division, and he did not employ sufficient detail to explain his hypothesis.

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[19] Ibid., pp. 215-16. [20] Ibid., p. 219.

[21] Ibid., p. 216; From this and from many others it is obvious to me that many stones usually thought of as natural are made from animals or from their parts by the medium of some terrestrial fluid, and that they the animals communicated to the clay or soft earth their shapes, and later perished, leaving their figures in stone, as careful observers can easily see in the form of scales on the stones of Eisleben.

Robert Boyle's <u>Essay</u> was a book much like Merret's.[22] Boyle, one of many children of a wealthy noble, was a chemist and a natural philosopher.[23] As Merret, Boyle was very interested in amassing details, but, unlike Merret, he went further to substantiate his ideas. Boyle wrote about such things as stones taken from a snake's head, stony wombs in the earth that harbored petrific liquors, the subtlety and penetratibility of such liquors, and skulls, bones, and pieces of wood excavated from the earth.[24] In addition, Boyle devoted a lengthy discussion to the origin of formed stones.

Boyle was apparently unsure whether all of the formed stones which he had observed were of organic origin and, as Merret again, was compromising in his answer. Boyle believed that all substances buried within the earth were subject to the action of one of three types of juices or fluids that operated beneath the surface of the earth.

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[22]Robert Boyle, <u>An Essay About the Origine & Virtues of Gems. Wherein Are Propos'd and Historically Illustrated Some Conjectures About the Consistence of the Matter of Precious Stones, and the Subjects Wherein Their Chiefest Virtues Reside</u> (London: Printed by William Godbid, 1672). This book was reviewed. See [Anon.], "An Accompt of Some Books. I. An Essay About the Origine and Vertues of Gems, by the Honourable Robert Boyl Esquire, Fellow of the R. Society," <u>Philosophical Transactions: Giving Some Accompt of the Present Undertakings, Studies and Labours. Of the Ingenious in Many Considerable Parts of the World</u>, VIII, No. 84 (June 17, 1672), 4095-97. Cited hereafter as <u>Philosophical Transactions</u>.

[23]Leslie Stephen and Sidney Lee (eds.), "Robert Boyle," <u>DNB</u>, II, 1026-31.

[24]Boyle, Essay, pp. 156-57.

These were the petrescent, the metallescent, and the mineralescent juices. These juices were responsible, according to Boyle, for the formation of many fossils.[25] The role of these fluids was dual. They both created formed stones of themselves and petrified other bodies. Petrescent juices, for example, made curiously figured bodies in experiments, and they also permeated wood, vegetables, animals, and other substances and turned them into stone.[26]

The operations of these juices in nature varied. They were found in many places, as many respected authors and the many kinds of collected fossil stones that were in museums and other places attested.[27] They functioned with or without the aid of petrifying waters; rain water often assumed the part of streams or ponds.[28] They were contained in soils; Boyle himself had often excavated figured stones from such earth.[29] They mixed with common waters; a lake both with petrifying waters and with living fish was discovered in northern Ireland.[30] A description of how petrific liquors acted ended this section.[31]

Boyle's conclusions were incomplete and inconclusive. He failed to account for the location of these

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[25] Ibid., pp. 5-6.

[26] Ibid., pp. 57, 98.

[27] Ibid., pp. 96, 147.

[28] Ibid., pp. 147-49.

[29] Ibid., p. 149.

[30] Ibid., p. 152.

[31] Ibid., pp. 153-55.

formed stones, and he did not firmly adopt either the organic or the inorganic solutions for their origin, although he did display a marked preference for the former. As Merret, Boyle separated formed stones from other stones only in name. Moreover, Boyle was extremely interested in the medicinal uses of stones, and spent much more space on this facet of activity, than he did upon that given to the question of the origin and nature of fossils.

John Ray's Observations was a different work.[32] Ray, a minister, a naturalist, and a Fellow of the Royal Society,[33] became interested in the fossil controversy and devoted large sections of many works to the explanation of these remains. After lengthy studies, Ray came to believe that these formed stones were nothing else but the remains of plants and animals. This feeling developed in Ray only gradually, however, and he bowed to the words of his friend Lister in his initial efforts, noting that

> Now whereas in this Narrative, discoursing concerning the petrifications of Shells, Fish-bones, &c. I have delivered as many opinion or conjecture, that those bodies, which are commonly known in England by the names of Star-Stones and S. Cutbert's Beads, were nothing else but the spines and tail-bones of some Fishes, I must own my self to have been therein

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[32]John Ray, Observations Topographical, Moral & Physiological; Made in a Journey Through Part of the Low-Countries, Germany, Italy, and France: with a Catalogue of Plants Not Native of England, Found Spontaneously Growing in Those Parts, and Their Virtues. Whereunto Is Added a Brief Account of Francis Willughby Esq; His Voyage Through a Good Part of Spain (London: Printed for John Martyn, 1673).

> mistake. For my learned and ingenious Friend, Mr. Martin Lister, hath lately advised me, that he hath found ramose and branched like trees: which doth sufficiently evince me that they were not of that original I supposed. Whereof unless we will grant them to be primary and immediate productions of Nature, as they are in the form of stones; we must embrace Mr. Hooke's opinion, that they were the roots of some Plants; though I confess I never as yet saw any Roots or Branches shaped and joynted in that manner.[33]

Despite this acquiescence, Ray soon after rejected Lister entirely.

Ray had based the Observations upon a trip abroad. There he had observed many public and private collections of fossils. He combined these with an enumeration of what stones were in England, where they were found, and which writers mentioned them. In England, there were serpent stones at Whitby, star stones at Shukborough, St. Cuthbert's Beads in Yorkshire, and many more. On the European continent, there were echinites at Brescia in Lombardy, *glossopetrae* at Lunenberg and at Antwerp, cockles in Hildesheim, and several others, most of which were listed by prominent authorities, or which were found in museums, such as the ones at Verona and Modena in Italy.[34] Besides these, Ray thought that more were elsewhere. The reason

> That they [shells] have not been discovered or taken notice of in other parts of Europe and in Asia and Africa is certainly to be attributed to the Negligence and Rudeness of the People who mind nothing that is curious, or to the want of learned Writers

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[33] *Ibid.*, p. [5].

[34] *Ibid.*, pp. 113-19, 218-19, 236.

who should communicate the Histories of them to the World.[35]

Of the many places discussed, the island of Malta was of special interest to Ray, both because of the large numbers of what were apparently the remains of the teeth of sharks and of other shell bones, and because of Steno's comments about these remains. Ray noted that Malta was flat and nearly at sea level and remarked that it was far easier for him to believe that these teeth and bones were the remains of what the sea had washed ashore, than what any plastic power had generated.[36] The earth of Malta was hardly two feet above rock, he wrote; in past times the sea probably laid in shallow pools at spots on the island, and beds of shell fish bred there. When the waters receded, decayed shell fish remained behind and petrified.[37]

There was another thoery that the teeth were what was left of sharks' heads which had been caught and eaten by fishermen for centuries, but Ray believed this was false and that Steno had provided the rebuttal for this. He had answered that sharks had sixty or more teeth, and constantly bred more, which were too many teeth for the other reply; the winds helped push the shark remains awash; sharks bred and lived in large schools and thereby produced too many teeth again for the other theory; and

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[35] *Ibid.*, pp. 119-20. [36] *Ibid.*, p. 294.

[37] *Ibid.*

finally, other shells found inland that were possibly similarly produced, as various cockle shells of marine origin, supported the belief in their organic production in shallow beds.[38]

Ray believed that shell fish everywhere, and not only on Malta, were of organic origin, but he wished to present a fair review of contrasting opinions upon this topic. His review, however, was anything except fair, as the largest portion of his discussion was devoted to the promotion of the theory of organic origin and to the refutation of what Ray considered to be the two principal objections to it. He pictured, for example, the theory of organic origins as one of unquestionable validity to the ancient philosophers and to the most acceptable of his contemporaries, wuch as Steno ". . . and Mr. Robert Hook, after whom I need name no more to give it countenance and gravity in the World."[39] He included a lengthy quote from Hooke's *Micrographia* and discussed Steno extensively.[40] By contrast, he briefly considered the inorganic origin of formed stones, quoted Lister's article of 1671 in the *Philosophical Transactions*, and dismissed this theory as ". . . a shift and a refuge to avoid trouble objections ."[41]

Ray was more concerned with the discussion of what

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[38] *Ibid.*, pp. 294-95.

[39] *Ibid.*, p. 120.

[40] *Ibid.*, pp. 120-25.

[41] *Ibid.*, pp. 127-31.

he considered were the two most important objections to the theory of organic origin. These were the apparent necessity of the earth being covered by the ocean for a long period and the discovery of many shell-like stones which had no counterparts among living stones.[42]

The first objection, an assumption that the sea had covered large areas for long time spans because shells were found two hundred miles inland in Germany and upon the Alps and other high mountains, agreed with neither reason nor Scripture. The Deluge of Noah, if caused by rains, would not have driven shells inland; and if this flood was abetted by waters from underground caverns, as some insisted the Biblical references to the breaking up of the fountains of the great deep must refer, the result would have scattered shells all about, and not concentrated them in beds in particular places, where they were now found.[43]

Another false proposal designed to replace this one of the universal flood was that the mountains were once under the sea, and that they had been raised by earthquakes. This idea was unlikely. Many mountains had shell remains, and all could not have been so elevated. If they were, then the whole earth must have been beneath the sea, a notion already refuted. There were few records of such

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[42] Ibid., pp. 125-27. [43] Ibid., pp. 125-26.

large earthquakes, and the mountains produced in these upheavals in no way compared to such mountain chains as the Alps and the Atlas ones. In addition, the process of mountain-building, if assumed to be true, and if the present mountains had not existed from the creation in their present state, required either a much older world than was credible or else a much more violent action of natural forces in past ages than in the present. Neither conclusion was warranted. Nature had endured little change in her history. Violent earthquakes were not the answer.[44]

The second objection, that many of these formed stones, if considered shell remains, were not now found alive, and that therefore they were not of organic origin because God forbade the destruction or loss of any created species, was contradicted by both Providence and evidence. Ray himself had seen species of genuses supposedly lost, and he was sure that further investigations would find others similarly presumed lost. Providence also supported this contention, Ray held, because it took special care that few, if any, of its works would be lost.[45]

Ray had thus seemingly established himself as a believer in the organic origin of fossils, but he was a cautious natural philosopher who was wary of authorities who contradicted him. In his preface, for instance, he

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[44]<u>Ibid</u>., pp. 126-27. [45]<u>Ibid</u>., p. 127.

bowed to the same Lister whom he had attacked in his text.

Ray's reticence to assert his ideas was a hindrance to their development. This was quite evident in the suggestion which he put forth in his essay that concerned two difficulties which were to trouble natural philosophers --their belief in the youth of the world, and their disbelief in the extinction of any of the organisms that God had created. Ray was ready to overcome both these problems, despite the theological implications connected to them; indeed, Ray had to overcome them, because he wished to retain, above all, his opinion that all formed stones were organic in origin. Nevertheless, despite his need, Ray was hesitant. He had stated, both in his Observations[46] and in a later article,[47] that some species were, for all that philosophers knew, lost out of the world, because they had no living counterparts. He also wrote, though, that the extinction of species was

> a supposition which Philosophers hitherto have been unwilling to admit, esteeming the destruction of any one Species to be a dismembring of the Universe and rendring it imperfect, whereas they think the Divine Providence is especially concerned to preserve and secure all the Works of the Creation.[48]

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[46] Ibid.

[47] John Ray, "A Letter of Mr. Martin Lister, Containing His Observations of the Astroites or Star-Stones; Communicated to the Publisher," Philosophical Transactions, X, No. 112 (March 25, 1675), 274-79.

[48] Ray, Observations, p. 127.

Ray displayed sympathy for the supposition of these philosophers in one of the objections that he took note of against the organic origin of formed stones. He mentioned that some of these stones apparently had no living counterparts, and that if further searches found nothing alive which resembled them, then proponents of organic origin ". . . must have recourse to that gratuitous supposition that such Species are lost out of the World."[49]

Ray's studies about fossils in his Observations were only the first in his works upon this subject. In these books, Ray treated his topic with painstaking care, and he reviewed current scholarship assiduously. He was original, and he presented his ideas well. In addition, he had sufficient conviction to render his views strongly and attractively, and he believed that the theory of the organic origin of fossils had the fewest obstacles.

The care which Ray had taken in his research was also shown by Paolo Boccone (1633-1704), who combined his diligence with a number of illustrations. Boccone, a Sicilian, described and attempted to account for the origin of several kinds of figured stones in his book, Observations Naturelles.[50] The types of stones described by

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[49]Ibid., p. 130.

[50]Paolo Boccone, Recherches et observations naturelles de Monsieur Boccone Gentilhomme Sicilien; touchant le corail, la pierre etoilée, les pierres de figure de coquilles, la corne d'ammon, l'astroïte undulatus, les

Boccone included bezoar stones, star stones, astroites, shell fish-like stones, cornu ammonis stones, and glossopetrae stones. He examined each of these in turn, and he gave descriptions and illustrations of them. He cited authorities who had considered them, and he concluded with his ideas about them. All of this material was in the form of short letters, of which there were twenty-nine in number.

Boccone treated bezoar stones as writers of countless lapidaries had in times past. He considered these stones to be minerals, and he cited many authorities to support this position. He was interested in their medicinal uses for such maladies as the stone, pleursey, malignant fevers, and other sicknesses.[51] He devoted a large section of his letter to further details about the bezoar stone, such as where they were found, what infirmities they overcame in particular cases, and how to prepare these stones

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dents de poissons pétrifées, les herissons alterez, l'embrasement du Mont Etna, la sangsüe du xiphias, l'alcyomium stupposum, le bezoar mineral, & les plantes qu'on trouve dans la Sicile, avec quelques reflexiones sur la vegetation des Plantes. Examinées à diverses fois dans l'assemblée de Messieurs de Sociéte Royale de Londres, & conferences dans les de Monsieur l'Abbé Bourdelot à Paris (Amsterdam: Chez Jean Jansson à Waesberge, 1674). See also [Anon.], "An Account of Some of the Natural Things, with Which the Intelligent and Inquisitive Signor Paulo Boccone of Sicily, Hath Lately Presented the Royal Society, and Enriched Their Repository," Philosophical Transactions, VIII, No. 99 (December 22, 1673), 6158-61.

[51] Ibid., pp. 225-31.

as medicines.[52]

Star stones, Boccone wrote, consisted of an aggregation of a great number of small tubes with spongy centers and with an infinite quantity of round regular cells which were dispersed in an even fashion.[53] The ends of these tubes had upon them small figures.[54] Many writers had taken notice of them. Some attributed them to be the work of a species of crystal, and others, such as Steno, to be the deposits of a great deluge.[55]

Astroites had nearly convex and porous surfaces, which were very singular. Some considered them to have aquatic origins, and others thought them the remains of vegetables.[56] Boccone believed that they were quite similar to the star stones, and that both were relics of marine plants.[57]

Besides star stones and astroites, Boccone held that many other curiously figured stones that were found on or beneath the surface of the earth were the remains of things which had once been alive. He thought that plants, animals, and similar bodies had, after death, become hardened and had taken the weight and figure of stones through the influence of petrifying salts. These

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[52] _Ibid._, pp. 231-54.

[53] _Ibid._, p. 119.

[54] _Ibid._, p. 121.

[55] _Ibid._, pp. 135-37.

[56] _Ibid._, pp. 142-43.

[57] _Ibid._, pp. 144-48.

salts effected their petrification by the invasion of the pores of numerous bodies, which they then caused to have stony natures. All types of once-living bodies, as numerous authors confirmed, were subject to petrification.[58] These included wood, fish teeth, vertebrae of animals, dog-fish, sea urchins, and many others.[59]

Prominent among these so-called formed stones were shell fish and *glossopetrae*. Boccone studied these, and he employed the microscope in his examinations of the lines and symmetry of the shell fish.[60] He noted that shell fish, such as the *cornu ammonis* or nautili, the cockles, and others, were believed by many to grow as minerals in the ground. He believed that there were too many similarities between them and living fish for this to be true. Accordingly, Boccone argued that these shell fish must therefore be the remains of living creatures.[61]

Glossopetrae, Boccone decided, were also the remains of living creatures. Found in immense quantities on the island of Malta, *glosscpetrae*, or serpent-tongues, were, Boccone noted, believed by many to be stones which had been generated in the earth, and whose various sizes were determined by the stage of growth in which they were. Actually, Boccone countered, they were the teeth of dog-fish and other allied species. This was so because of

[58] *Ibid.*, pp. 296-302. [59] *Ibid.*, pp. 148-53.

[60] *Ibid.*, p. 304. [61] *Ibid.*, pp. 304-306, 311-14.

their close resemblance in shape to the bones of these living fish. Boccone wrote, however, that he was not sure of this, for although he had found jaw bones with teeth, he had never yet encountered teeth in place in the jaw. As he remarked:

> . . . Mais j'enclin fort à l'opinion de ceux qui croient que les Glossopetres sont pour la pluspart des dents du poisson Carcharias, où Chien de mer, ou poisson appellé Piscis Aquilae, & d'autres Poissons de cette nature tant a cause des raisons que me donnent les sens que pain les conjectures que je vous proposeray dans la suite. Dans l'Isle de Malthe les petrifications de diverses parties d'animaux sont tres-communes, j'ay recouvert trois especes d'Herisson entiers petrifiez, comme je les montray une fois a cette illustre Compagnie, J'ay trouvé aussi des Pierres assez conformes aux parties naturelles des animaux, & mesme j'ay ven des especes de Cancer que estoient alterées, & avoient leur crouste petrifée, laquelle estoit sort distincte de l'argille qui avoit pris place dans les vuides de tout l'ecorce, & de plus il conservoit les points, & des autres signes qu'on voit dans la surface de cet Animal; de sort que si on pouvait anatomiser les Dents du poisson Carcharias fraîchement arrachées, vous trouveriez que leur surface, leur racine & la pouche où sont refermées ses dents, sont de la mesme structure & de la mesme composition que l'on voit dans les differentes especes de Glossopetre de Malthe. En effect ces Glossopetres se sendent souvent en long comme les guaînes des dents du poisson Carcharias.
>
> Quoy que je n'aye pas trouvé les machories entieres du poisson Carcharias, du poisson Carris, du poisson Requiem & de l'Aquilae petrifiez avec les dens renfermées dans la machoire; neanmoins je ne puis abandonner l'opinion de ceux qui croyent que les Glossopetres soint des Dents de poisson petrifiez, . . .[62]

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[62] Ibid., pp. 315-16:

But I am inclined to have the opinion of those who believe that these glossopetræ are for the most part teeth of the carcharias, or of the dog-fish, or of the eagle fish, and of other fish of this nature, because of what the senses tell me. This has much to do with the

Boccone's rigidity of belief was supported by evidence drawn from his imagination; such evidence among natural philosophers was always more conclusive than any material facts. He presented two plates which illustrated "Dents petrifiées dites Glossopetres." Next to these teeth were three jaws, each from different species of living sharks. Two of these jaws had their teeth in place.[63]

Boccone concluded his book with a brief summary of the views of Colonna and Steno on _glossopetræ_, with both of whom he agreed.[64]

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following conjectures that I shall propose. On the island of Malta petrifications of diverse parts of animals are very common. I have collected three species of urchins entirely petrified, as I demonstrated at one time to this illustrious company. I have also discovered some rocks quite similar to natural parts of animals, and I have even seen some species of cancer which were altered, and had their crust petrified. These were very distinct from the clay which had taken [their] places in the spaces in the shell. Moreover, they retained the marks and the other signs that are seen on the surface of this animal, so that if one could dissect the teeth of the carcharias freshly caught, one would discover [how alike were] their sufaces, their roots, and their jaws where they have shut their teeth. They are of the same structure and composition as is seen in the different species of _glossopetræ_ on Malta. These are often found as long in length as the roots of the teeth of the carcharias.

That which I have not discovered [is] the entire petrified jaw of the carcharias, or of the dog fish, or of the shark, or of the eagle fish, with the teeth set in the jaw; nevertheless I am not able to abandon the opinion of those who believe that the _glossopetræ_ are the teeth of petrified fish, . . .

[63]_Ibid._, p. 314: "petrified teeth called _glossopetrae_."

[64]_Ibid._, pp. 319-28.

The work of Boccone and his immediate predecessors had tended to the accumulation of a mass of evidence to support their postulate that formed stones had an organic origin. Unfortunately, they had failed to recognize that a postulate did not by definition require proof. Nevertheless, they were convinced, as were an increasing number of natural philosophers in the following years, that they had indeed proved their postulate correct by means of facts.

So believed Nehemiah Grew (1641-1712). Grew, a physician and for a time Secretary of the Royal Society,[65] epitomized the collector with his huge, well-illustrated volume on the Museum of the Royal Society.[66] He was thorough. He examined both what he believed were petrified animal and vegetable bodies. He described these petrifications, provided illustrations for a few of them, mentioned many authorities who had written about them, and catalogued them into groups. Impressive in particular in all this work was Grew's division of petrified shell fish into seven classifications, or "schemes."[67]

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[65]Leslie Stephen and Sidney Lee (eds.), "Nehemiah Grew," DNB, VIII, 609-611.

[66]Nehemiah Grew, Musaeum Regalis Societatis. Or a Catalogue & Description of the Natural and Artificial Rarities Belonging to the Royal Society and Preserved at Gresham Colledge. Made by Nehemiah Grew M.D. Fellow of the Royal Society, and of the College of Physicians. Whereunto Is Subjoyned the Comparative Anatomy of Stomachs and Guts. By the Same Author (London: Printed by W. Rawlins, 1681).

[67]Ibid., pp. 150-53.

Grew half-heartedly attempted to be neutral in his presentation of both the inorganic and organic theories of the origin of fossils:

> It hath been much disputed, and is not yet resolv'd, of many subterraneal Bodies, which have the semblance of <u>Animals</u>, or <u>Parts</u> of them, Whether they were ever such, or no. And I am not ignorant of the Arguments offer'd on both hands. If I may speak my own sense a little, Why not? Is there any thing repugnant in the matter? . . .
>
> On the other side: although Nature cannot be said to imitate Art, yet it may soon fall out, that the effects of both may have some likeness. . . . But there can be no convincing Argument given why the Salts of Plants, or Animal Bodies, washed down with Rains, and lodg'd under ground, should not there be disposed into such like figures, as well above it?[68]

He claimed to make no efforts to resolve which theory of the two was more acceptable to him, but in his book he made his choice. He classified shells that many had attributed to the plastic power of salts under his heading of petrified animal bodies.

He also answered two of the standard arguments against the organic origin of formed stones which had the forms of shells--that they were found underground so far from the sea, and that so many of them resembled nothing living. The first, he noted, was answered by evidence; there were shells far from the sea because observation indicated this. The other, Grew continued, was accounted for by our ignorance. Grew estimated that less than one-half of the shell species alive then were known to men,

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[68] <u>Ibid</u>., pp. 253-54.

implying that these unknown shells would match the petrified ones, and incidentally preserving any species from destruction.[69]

One of the contributions of Grew in his book was the list that he provided of contributors to his museum, because it indicated an interest in such collections. The list contained seventy-eight names, and included such people as Robert Boyle, Robert Hooke, Martin Lister, Christopher Merret, Robert Plot, and many more.[70]

The writings of these men and others showed, in the last two decades of the seventeenth century, that a number of authors believed in the organic origin of fossils, and that the works of these men slowly acquired a new orientation. They were more sure of their theoretical basis, and they devoted less space to the discussion of the relative merits of the organic and inorganic theories. Instead, they turned to the implications and questions aroused by the assumption of the validity of the organic theory, and they started to discuss such hitherto secondary problems as the extinction of species and the deposition of fossils by the flood of Noah. The fossil controversy had thus once again shifted from an academic squabble to an involvement in nature's whole scheme of things.

Not all this was immediately apparent in the next book of consequence to appear that considered fossils,

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[69] Ibid., p. 253. [70] Ibid., p. [387].

John Ray's Miscellaneous Discourses.[71] In it, Ray concerned himself with a re-affirmation of the traditional Christian world outlook, which he saw as threatened. Ray thought that it was necessary to set forth a concept of nature that agreed both with this view and with the latest scientific investigations, and which would consequently preserve the old theology by incorporating within it features from the new and strange in natural philosophy.

In pursuing this ideal, Ray acted within the bounds of a time-honored tradition of Christian philosophers, who had for ages considered natural philosophy, as every other endeavour, secondary to religion. What was special about Ray was that he was eminent, not in his vocation as a minister, but rather in his avocation as a scientist. The two fields were perhaps, however, inseparable in his mind, and seemed to be so in what he announced in his preface that he intended to demonstrate as true in the text of his book:

> 1. That the World was formed out of a Chaos by the Divine Wisdom and Power. 2. That there was once an universal Flood of Waters, in which all Mankind perished, excepting some few that were saved in an Ark or Ship. 3. That the World shall one day be dissolved by Fire. 4. That there is a Heaven and an

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[71] John Ray, Miscellaneous Discourses Concerning the Dissolution and Changes of the World. Wherein the Primitive Chaos and Creation, the General Deluge, Fountains, Formed Stones, Sea-Shells Found in the Earth, Subterraneanous Trees, Mountains, Earthquakes, Volcanoes, the Universal Conflagration and Future State, Are Largely Discussed and Examined (London: Printed for Samuel Smith, 1692).

Hell, a *Tartarus* and an *Elysium*, and both eternal, . . .[72]

The role of fossils in this world of Ray was to support his contention that the Deluge was a miracle, because its material effects in the deposition of organic remains were of little moment. Ray therefore had two tasks: to show that these fossils were the remains of living organisms, and to determine how those of marine origin were so far inland, if they were not brought by the Deluge. The first he replied to by a review and a commentary upon recent authors who had considered the subject; the second he only partially answered.

Ray was convinced that all bodies that were found in the earth which had the shapes of animals, including the shells, teeth, and bones of fish, were what they resembled, and he was determined to answer all objections to his belief.[73] He noted that there were many of these, which were held by those who defended the theory that shells and bones were imitative reproductions of nature. These exceptions were that a theory of organic origin, if true, required a universal flood of a long duration; an extinction of some species of shell fish; the discovery of bivalvular shell fish with both shells, and not just one; the alternative of either a concentration or a dispersion of shells of the same species, and not both; and the completion of

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[72]*Ibid.*, p. [2].

[73]*Ibid.*, pp. 109-110.

the formation of the shells before they became petrified.[74]

As for the first, Ray wrote, it did seem unlikely that beds of shells had been deposited high in the Appenines and Alps and there given time to breed but by any other agency than a universal deluge. Such a flood, however, was contrary to both Scripture and to reason. The Deluge lasted only ten months, and probably covered those mountains only one-half of that time. Moreover, if the waters were so high for so long, they must have raised the oceans as well. If so, what became of them? Ray remarked that he really had no other reply to this objection, other than to suppose it might have happened.[75]

There was another difficulty allied to this first objection, Ray observed. How else than by the means of repeated inundations could one explain the beds of shells in mountains, which rested in several layers of strata, one above the other? Ray thought that the explanation was that these mountains were once on the bottom of the sea, and were raised--how he did not postulate--later.[76]

For the second, Ray noted that philosophers were unwilling to admit that any species was extinct, because the loss of any was an affront to the Creator, Who had taken such care to preserve all the animals in the ark.

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[74] *Ibid.*, pp. 116-27. [75] *Ibid.*, pp. 116-18.

[76] *Ibid.*, pp. 118-19.

Nature buttressed this conclusion, although many, as did Lister, found species which had no living counterparts,

> it is possible that many sorts of Shell Fish may be lodged so deep in the Seas, or on Rocks so remote from the Shores, that they may never come to our sight.[77]

Shell fish were recently found, for example, in southern oceans, which were as big in diameter as some of the petrified cornu ammonis.[78] Furthermore, no petrified shells were found, Ray declared, which were any larger than those which were then alive in the seas about England, despite assertions to the contrary.[79] There was difficulty in this regard, mainly with the cornu ammonis, or ophiomorphite stones, which many had tried to solve by an identification of them as a species of nautili. Ray cited authors both in opposition to and in favor of this postulate, and sided with the former. He believed, though, in the manner of all who were fond of their own theories, that cornu ammonis shell fish would be found.[80]

For the third and fourth exceptions Ray presented the same argument. It was inconceivable, Ray thought, that shells which Plot, the objector, admitted so exactly resembled living ones, could be considered otherwise, because some of them were found with one of two shells missing and because some species were found in groups

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[77] Ibid., pp. 119-20. [78] Ibid., p. 120.

[79] Ibid., pp. 120-21. [80] Ibid., pp. 121-25.

while others of the same species were found scattered. There was some reason for these occurrences, but none was readily available.[81]

The fifth objection, that some stones seemed to be in the process of completion (<u>in fieri</u>) was also raised by Plot.[82] Ray studied the selenites and clay cockles that Plot offered as evidence, and agreed that the selenites were formed in the same way as crystallized salts. Ray was not convinced about the clay cockles, though, and asked Plot for more proof.[83]

Ray concluded that these five objections were not persuasive. Nor did he consider Plot's other arguments plausible.[84] Shell fish were found loose that when alive clung to rocks, but they probably were rubbed off the rocks by either an accident or else by birds which pried them free in order that they might feed upon their meat.[85] Crustaceous shells, such as those of crabs and lobsters, were not found because they were rare in English waters and because they were less durable than the testaceous kinds.[86] Finally, <u>brontiae</u> did have living representatives, and were not lost, as Plot suggested.[87]

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[81] <u>Ibid</u>., pp. 125-26.

[82] <u>Ibid</u>., p. 126.

[83] <u>Ibid</u>., pp. 126-27.

[84] <u>Ibid</u>., pp. 127-29.

[85] <u>Ibid</u>., p. 127.

[86] <u>Ibid</u>., pp. 127-28.

[87] <u>Ibid</u>., pp. 128-29.

Ray conceded, however, with his usual caution:

> But to give these Arguments their due, though they be not demonstrative proofs, yet they infer a great degree of probability, and shrewdly urge and shake the contrary Opinion.[88]

Ray next proceeded to explain why he believed that shells were the remains of once-living organic beings. Nature did nothing in vain, he argued. Nor did it, as the atheists declared, do things by chance.[89] The shells that were found must have been made for a purpose, which was to cover an animal. Furthermore, they were clearly that which they had similar shapes of; the glossopetrae on Malta were nothing else but sharks' teeth,[90] as Fabio Colonna had shown.[91]

Ray had thus far argued that these shells must have been the remains of animals because of evidence that supported this postulate; he then argued for their organic origin because of the lack of evidence for other opinions. An example of this was rock plants. Those who chose a non-organic origin for them, he wrote, often wondered why only shells and bones of fish were found, and not other remains, such as horns and hoofs of land animals and plants.[92] These philosophers denied the evidence in front of them, which indicated that rock plants were organic.

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[88] Ibid., p. 127.

[89] Ibid., p. 109.

[90] Ibid., pp. 109-110.

[91] Ibid., pp. 110-14.

[92] Ibid., p. 114.

They gave, in addition, no other adequate account for another beginning for these plants.

> For that they [rock plants] do not shoot into that form after the manner of salts, may be proved by many Arguments. First, All Salts that shoot their Crystals or Concretions, are of one uniform substance, and their Figures are more simple, and may be owing to the Principles whereof they are compounded: in other Bodies that shoot, as the Pyrites and Belemnites, one might observe streight Radii or Fibres proceeding from one Center. Secondly, Did those Bodies shoot into these figures after the manner of Salts, it seems strange to me, that two Shells should be so adapted together at the heel, as to shoot out to the same extension round, and the upper and nether Valve be of different Figure, as in natural Shells. Thirdly, Were those Bodies produced in the manner of saline Concretions, its strange there should be such varieties of them, and their shapes so exactly circumscribed; so great a diversity of Figures, arguing a greater variety of Salts, or of their modifications and mixtures, than are likely to be found in Nature; and the Curvilineous Concretions of Salts never, that I have yet seen, appearing in that regularity of Figure and due Circumscription, as in these Bodies which is an Argument of some Principle, superior to Matter figured and moved, in their Formation.[93]

Ray was either evasive or noncommittal in his explanation of the part that the Deluge played in his world, because he wished to exclude it from his world except as a miracle that had no lasting effects. Accordingly, he accepted the Biblical Deluge.[94] He explained that it was caused by a shift in the center of the earth. This forced the oceans to press upon the subterranean abyss, which broke under the stress and loosened the fountains of the deep. The oceans rose, probably aided by great pressures,

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[93]Ibid., pp. 114-16. [94]Ibid., p. [2].

and covered the earth.[95] Many supposed changes were wrought by this flood; Kircher, Ray noted, presented a map and a description of these alterations.[96] Principal for some philosophers among these imaginary changes, Ray added, was the deposition of shells and shell fish all over the earth, and even in the Appenines and Alps.[97]

Ray denied this deposition of shells by the Deluge. It was true, he admitted, that shell beds were located in mountains, as several recent discoveries had confirmed.[98] He speculated that these shells might have been left there by waters that arose within a possible underground abyss that could have opened to the ocean at the time of the Deluge. The shells could have mixed with these internal waters, and could have been carried up under the mountains.[99] However, this was mere conjecture to Ray. He gave a number of reasons why the Flood had not deposited the shells: the period of the Deluge was too brief and too violent for them to breed in colonies[100]; the shells were laid in strata, which implied a later elevation of land or sedimentations from successive floods, and not a deluge[101]; a long flood might have destroyed some species of shell fish[102]; and,

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[95]Ibid., pp. 98-101.

[96]Ibid., p. 102.

[97]Ibid., p. 104.

[98]Ibid., pp. 132, 258.

[99]Ibid., pp. 130-31.

[100]Ibid., pp. 116-17.

[101]Ibid., pp. 118-19.

[102]Ibid., pp. 119-120.

finally, Ray mentioned that he had observed a large stone which was as hard as marble. It was marked throughout with so many cockles and their striae that it appeared to be nothing more than a mass of cockles held together by a stony cement. The cockles in it, Ray concluded, must have been broken into many small pieces before their concretion. No flood or sea could have accomplished this fragmentation.[103]

Ray's treatment of fossils was clear and developed. He had carefully collected data and had consulted authors before he set forth his own postulates, in many of which he had been ready to question well-established tenets, such as the ones on the age of the world and on the preservation of species. Ray, though, was too conservative to do more than question in most instances. Nevertheless, he had remained firm in his fundamental conviction that fossils were organic remains.

Far less bound than Ray to the thinking of the established society was Robert Hooke. Hooke had long been satisfied that the fossil remains which he had examined were the remains of plants and animals, and when he sought to explain how they came to be located so far from their original homes, he enunciated ideas that were novel and suggestive. These ideas were summarized in a work

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[103] Ibid., p. 130.

published soon after his death.[104]

Hooke began with a division of fossils into two classes. The first class included figured bodies of salts, talcs, spars, crystals, diamonds, and other mineral substances. The second class embraced two kinds of substances. The first were petrifications, or bodies that had been changed into stone, such as bones, teeth, shells, fruit, wood, moss, mushrooms, and many other animal and vegetable matters. The second were impressions of bodies, which were mineral and earthy substances, as clays, sands, earths, and flinty juices, that had been filled up and had been molded into the shapes of other bodies, as bones, fruits, and

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[104] Robert Hooke, The Posthumous Works of Robert Hooke, M.D.S.R.S. Geom. Prof. Gresh. &c. Containing His Cutlerian Lectures, and Other Discourses, Read at the Meetings of the Illustrious Royal Society. In Which I. The Present Deficiency of Natural Philosophy Is Discussed of, with the Methods of Rendering It More Certain and Beneficial. II. The Nature, Motion and Effects of Light Are Treated of, Particularly That of the Sun and Comets. III. An Hypothetical Explanation of Memory; How the Organs Made Use of by the Mind in Its Operation May Be Mechanically Understood. IV. An Hypothesis and Explication of the Cause of Gravity, or Gravitation, Magnetism, &c. V. Discourses of Earthquakes, Their Causes and Effects, and Histories of Several; to Which Are Annext, Physical Explications of Several of the Fables in Ovid's Metamorphoses, Very Different from Other Mythologick Interpreters. VI. Lectures for Improving Navigation and Astronomy, with the Description of Several New and Useful Instruments and Contrivances; the Whole Full of Curious Disquisitions and Experiments. Illustrated with Sculptures. To These Discourses Is Prefixt the Author's Life, Giving An Account of His Studies and Employments, with an Enumeration of the Many Experiments, Instruments, Contrivances and Inventions, by Him Made and Produc'd as Curator of Experiments to the Royal Society Pub'd by Richard Waller, R. S. Secr. (London: Printed by Sam Smith and Benj. Walford, 1705).

especially shells. These latter substances received their names from the things that they had shapes similar to, as brontias, glossopetrae, and many more.[105]

Hooke remarked that the curiosity of men had been aroused by these oddly-shaped petrifications and impressions, and that accordingly many explanations had been proposed to account for the manner of their formation. Some of these explanations included such theories as that of the operations of a celestial influence, but most authorities relied upon some vegetative or plastic virtue inherent in the earth for explanatory purposes. Hooke declared that he agreed with none of these theories, and that he intended to propose his own.[106]

Hooke commenced his assumptions with an enumeration of the phaenomena. First, there were many shells found in many countries which resembled sea shells in shape, as many credible authors had affirmed. Their location was a mystery, which some solved by a celestial influence, and others by a plastic virtue inherent in the earth. Second, many bodies were similarly found which resembled vegetables. Third, there were many bodies found within the earth of a less durable nature than shells, such as bodies resembling in whole or part fish and other animals and vegetables, for example, claws, horns, teeth, mushrooms, woods, roots,

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[105] Ibid., pp. 280-81. [106] Ibid., pp. 287-88.

leaves, and so forth. These were stones in all but shape, and were called by such names as star stones and snake stones. Fourth, many of the shells were found in the Alps and in other mountains, sometimes hundreds of miles away from the sea. Fifth, often these shells were observed far above sea level. Sixth, they were conversely frequently seen far below sea level, encased in rock and metal in mines and wells, of which latter location was instanced by a report of Bernhard Varen at Amsterdam. Seventh and last, figured bodies or shells were commonly discovered embedded in hard and dense stone near the surface of the earth, as in marbles and flint. Some of these stones had so many shells that they appeared to be nothing but amalgamations of shells.[107] Hooke next asked if these bodies were real remains, or else mimics of nature. If they were mimics, why should nature play tricks? If they were real, how did they arrive in such unlikely places?[108]

Hooke believed that they were real, and he both noted and attempted to answer all objections to his belief. The objections included, first, how did these shells, woods, and other bodies come to be where they were now; and second, why were so many of them composed of clay, chalk, marble, and other substances, which were of a composition different from that of the shells or other bodies that they

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[107] Ibid., pp. 288-89. [108] Ibid., p. 289.

represented.[109] Hooke thought that these objections, and others less worthy of notice, could be met by the supposition of a number of propositions. First, most of those curiously shaped bodies were the animal or vegetable substances which they resembled. Some were pieces of matter which had been cemented together by petrifying juices that had infiltrated their interiors and then had hardened; others were impressions made from those substances by a soft matter that later had petrified. This resulted either from an external envelopment of the remains by the liquid, or by an internal filling of the fossil with the liquid. Second, an external force assisted these stones in the process of petrification. Third, it was probable that this force was one of these four: a fiery exhalation from an underground earthquake; a saline substance; a glutinous or bituminous matter; or cold and compression operating over a long period. Fourth, water itself can be petrified with the passage of time. Fifth, many other substances have congealed into hard bodies with time. Sixth, many parts of land since the creation have since been submerged, and new lands have arisen. Seventh, part of Britain was once under water. Eighth, most places where formed stones have been found were once under water and rose either by subterranean fires or by earthquakes. Ninth, the Alps, the

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[109] Ibid.

Apennines, and other mountains had been all probably once under water, and had been elevated by underground earthquakes. Tenth and finally, some species of creatures have probably been destroyed in past times, and new ones created.[110] Hooke concluded with an attempt to confirm his conjectures.[111]

Violent change was the most important factor in the world to Hooke. It explained, he believed, in a satisfactory manner what he understood to be the most difficult obstacle to the acceptance of the organic origin of fossils--their location, without, notably, relying upon the Deluge of Noah for their deposition. The forces of nature effecting this change could be seen now at work. Sea had become land, and the plains had become mountains, and vice versa, through the action of winds, waters, gravity, volcanoes, and earthquakes.[112]

Of all these agencies of change, the strongest and most efficient had been that of earthquakes and like eruptions. Earthquakes had operated all over the world, and their effects had been felt everywhere. They had raised land, made islands, deposited new ground upon old, created depressions in the surface, fashioned lakes, forced seas to inundate plains, and did other works. Earthquakes

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[110] Ibid., pp. 289-91. [111] Ibid., pp. 291-98.

[112] Ibid., p. 290.

provided the most reasonable answer to the questions about the causes of both the Deluge of Noah and of the first separation of land from waters at the time of the creation. It was true, Hooke admitted, that no recent earthquakes had occurred that were of the magnitude of those which he described, but small mountains had been elevated and sea and land had been transposed by the operations of this power, as many accounts testified. Probably in past times, Hooke added, the operations of earthquakes had been much stronger, because the earth was younger and in a less settled state, and there was a greater supply of combustibles beneath the surface of the ground that would burn and so provoke these upheavals. This would account for the disappearance of Atlantis that Plato (427-347 B.C.) had related, and it was likely that the same earthquake that had sunk Atlantis had thrown Britain, complete with oysters and other shells, up from the floor of the ocean.[113]

Flux was the order for the organic world as well as for the terrestrial world, Hooke continued. It was inconceivable that parts of the world could be destroyed and that all of the species could survive, and it was more plausible that

> there may have been divers Species of things wholly destroyed and annihilated, and divers others changed and varied, for since we find that there are some kinds of Animals and Vegetables peculiar to certain places,

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[113] *Ibid.*, pp. 298-312.

> and not found elsewhere; if such a place have been swallowed up, 'tis not improbable that those Animal Beings may have been destroyed with them; and this may be truth of aerial and aquatick Animals. For those animated Bodies, whether Vegetables or Animals which were naturally nourished or refresh'd by the Air would be destroyed by the Water. And this I imagine to be the reason why we now find the shells of divers Fishes Petrify'd in Stone, of which we have now none of the same kind.[114]

Not only, Hooke continued, were old species destroyed, but new varieties of old species were created as probable by-products of changes in soil and climate brought about by the alterations of land by the earthquakes.

> That there may have been divers new varieties generated of the same Species, and that by the change of the Soil on which it was produced; for since we find that the alteration of the Climate, Soil, and Nourishment doth often produce a very great alteration in those Bodies that suffer it, 'tis not to be doubted but that the alterations also of this Nature may cause a very great change in the shape, and other accidents of an animated Body. And this I imagine to be the reason of that great variety of Creatures that do properly belong to one Species, as for instance, in Dogs . . . if these or any other animated Body be thus transplanted, 'tis not unlikely but that the like variation may follow; and hence I suppose 'tis that I find divers kinds of Petrify'd Shells, of which kind we have none now naturally produced; . . .[115]

The destruction of plants and animals, and the concurrent variations of older species into newer forms was characterized, as Hooke saw events, as a devolutionary process. Noah's Flood, initiated by earthquakes, had not only brought about this loss, but it had destroyed an entire human civilization which was far superior to any which

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[114] Ibid., p. 327. [115] Ibid., pp. 327-28.

succeeded it. It was a fitting punishment from God to man for his many sins.[116]

Hooke further developed his theses of the devolution and of the decay of the earth and its creatures to encompass their degeneration. He quoted at length the Metamorphosis of Ovid (43 B.C.?-17 A.D.) and thoroughly agreed with what he thought that that Latin writer had meant to say about the history of the earth.[117] He buttressed his use of Ovid's work with notes from the writings of Hanno the Carthaginian (fl. c. 500 B.C.) and Varro (82-36 B.C.) and from those of later writers such as René Descartes (1596-1650) and Thomas Burnet (1635?-1715).[118] According to Hooke's interpretations of and conclusions from Ovid, the earth was in the third of three stages of life. At the beginning, there had been a golden age, when the surface of the earth was soft, smooth, and pliable. At this time, the earth had the full vigor of youth, and its forces engaged in violent activity. Earthquakes and eruptions were common, of which Ovid's description of the battles of giants was in reality an account.[119] Then the Earth matured into the silver age and dried and hardened. The activity of its agents slowed. Now it was in the iron age, and its surface had petrified and it had become crossed

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[116] Ibid., pp. 328-30.

[117] Ibid., pp. 371-84.

[118] Ibid.

[119] Ibid., pp. 378-84.

with the marks of time etched upon its surface, making it uneven. Earthquakes and floods added to its afflictions.[120]

Hooke reasoned that the decay of the earth could scarcely produce better results in the variation of species of which he had spoken. The new creatures and plants would reflect the worsening of their environmental conditions, which, as Hooke enunciated another fruitful idea, must have some effect upon them.

> . . . we will, for the present, take this Supposition to be real and true, that there have been in former times of the Word [sic], divers Species of Creatures, that are now quite lost, and no more of them survivuing [sic] upon any part of the Earth. Again, That there are now divers Species of Creatures which never exceed at present a certain Magnitude, which yet, in former Ages of the World, were usually of a much greater and Gygantic Standard; suppose ten times as big as at present; we still grant also a supposition that several Species may really not have been created of the very Shapes they now are of, but that they have changed in great part their Shape, as well as dwindled and degenerated into a dwarfish Progeny; that this may have been so considerable, as that if we could have seen them both together, we should not have judged them of the same Species. We will further grant there may have been, by mixture of Creatures, produced a sort differing in Shape, both from the Created Forms of the one and other Compounders, and from the true Created Shapes of both of them.[121]

Hooke pursued this topic further and, using an analogy of natural processes, concluded that some species were extinct:

> For first we do find that all individuals are made of such a Constitution, as that beginning from an Atom, as it were, they are for a certain period of Time increasing and growing, and from thence begin to decay,

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[120] Ibid., pp. 424-33. [121] Ibid., p. 435.

> and at last Die and Corrupt. And in every part of their Life they are in a continual change or progress, from more perfect to imperfect, there being a continual growth of Death and Decay to the final Dissolution; yet this is not Argument against the Omnipotence, Providence and Wisdom of the Creator, who thought fit so to Create them. . . . As we see that there are many changings both within and without the Body, and every state produces a new appearance, why then may there not be the same progression of the species from its first Creation to its final termination? Or why should the supposition of this be any more a derogation to the Perfection of the Creator, than the other, besides, we find nothing in Holy Writ that seems to argue such a constancy of Nature, but on the contrary many Expressions that denote a continual decay, and a tendency to a final Dissolution; and this not only of Terrestrial Beings, but of Celestial, even of the Sun, Moon and Stars and of the Heavens themselves. Nor have I hitherto met with any Doctrine among the Philosophers, that is repugnant to this Doctrine, but many that agree with it, and suppose the like States to happen to all the Celestial Bodies, that is, to the Stars and Planets that happen to the Individuals of any Species, and consequently if the Body of the Earth be accounted one of the number of the Planets, then that also is subject to such Changes and final Dissolution, and then at least it must be granted, that all the Species will be lost; and therefore, why not some at one time and some at another?[122]

Hooke had thus maintained that variations of species had occurred because of changes in terrestrial conditions, and that certain species had become extinct, not because of their inability to adapt to such alterations, but because these changes were so violent that they destroyed entire species.

Basic to Hooke's arguments, therefore, was his belief in violent upheavals, which were chiefly embodied

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[122] Ibid., pp. 435-36.

in the form of earthquakes. He attempted to substantiate this belief with recent evidence, and he gathered together relations from all quarters. He was especially concerned with reports about new discoveries of fossils and with accounts about earthquakes and volcanoes. For example, he mentioned Tentzelius's-Wilhelm Ernst Tentzel (1659-1707)-story of the skeleton of an elephant found buried fourteen feet deep in Saxony.[123] He cited the current excavations of subterranean trees in Italy, France, Germany, and other places.[124] He noted the discoveries of parts of the head of a hippopotamus in Kent; of the bones of a "mammatoroykost" in Siberia, which he thought was probably an elephant; of the bones and teeth of an elephant in Pomerania; and of large horns in Ireland.[125] He went into great detail, in order to refute the deposition of fossils by the Deluge of Noah, to support the story of the finding of a ship with a crew of forty, which was buried a hundred fathoms underground in Switzerland.[126] He reprinted a newspaper account of a tremendous and tragic earthquake that had occurred in the East Indies,[127] and he related many other terrible contemporary natural happenings, such as hurricanes at Barbadoes and at Madrid[128]; earthquakes in China,[129]

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[123] Ibid., pp. 436-37.

[124] Ibid., p. 437.

[125] Ibid., pp. 438-39.

[126] Ibid., pp. 439-40.

[127] Ibid., p. 437.

[128] Ibid., p. 429.

[129] Ibid., pp. 429-30.

at Lima,[130] in Jamaica, in Sicily, and in Norway[131]; and volcanic eruptions in Sicily.[132] All of these observations of natural forces in operation were, Hooke believed, sufficient proofs for his hypothesis of a world unstable both in its past and in its present.[133]

Hooke had used fossils to satisfy his determined conviction that the world had undergone awesome and frequent changes, but he was aware that his conclusions might seem unreliable to other natural philosophers. For these conclusions to be otherwise to them, they needed to believe that fossils were organic remains, for fossils were central to Hooke's arguments. If they did not, Hooke's other ideas were useless. Some did not. They reasoned that Hooke's ideas about eruptions and other changes were not confirmed either in secular or in Scriptural works and that to suppose that fossils were really organic remains would require these unrecorded events. Many also argued, as did Lister, that an organic origin of these stones, despite Ray's objections, would mean that some species were extinct, which was a disturbing thought, because it meant to them that Providence had neglected some of His creations. Many, however, were convinced by this time that fossils were organic remains, and so Hooke

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[130] Ibid., p. 432.

[131] Ibid., p. 440.

[132] Ibid., p. 426.

[133] Ibid., p. 440.

was relatively free to suggest that fossils did indeed indicate such an earth history as he had proposed.

> 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 any unbiassed Person, and therefore he has no reason to scruple his assent: nor to desist from making his Observations to correct his natural Chronology, and to conjecture how, and when, and upon what occasion they came to be placed in those Repositories. These are the greatest and most lasting Monuments of Antiquity, which, in all probability, will far antidate all the most ancient Monuments of the World, even the very Pyramids, Obelisks, Mummys, Hieroglyphicks, and Coins, and will afford more information in Natural History, than those other put together will in Civil.[134]

Hooke even suggested that there were media or criteria of chronology among fossil remains, which could give some account of dates, but he did not discuss this further,[135] except to reiterate that such a chronology was a distinct possibility.

> . . . Men do generally too much flight and pass over without regard these Records of Antiquity which Nature have left as Monuments and Hieroglyphick Characters of preceding Transactions. . . And tho' it must be granted, that it is very difficult to read them, and to raise a Chronology out of them, and to state the intervalls of the Times wherein such, or such Catastrophes and Mutations have happened; yet, 'tis not improbable, . . . by the help of . . . other means and assistances of Information, . . .[136]

In all of these arguments Hooke was simultaneously a conservative and a revolutionary. He accepted most of the current views about the earth's history. He believed

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[134] Ibid., p. 335. [135] Ibid.

[136] Ibid., p. 411.

that God had created and had ordered the world according to a broad plan; that the world had a brief and violent past; that it had declined from its original perfection chiefly because of man's wickedness; and that the Bible was a true account of both the history of man and of his abode, and that it agreed with studies of natural history. He also believed, however, that some species were extinct and that fossil remains were a reliable record of the past. Herein lay the boldness of Hooke's originality. He saw the implications, as Ray had, in his examinations of fossils; unlike Ray, he was philosophically able to accept these implications. As Hooke wrote, some had remarked of him that he had ". . . turned the World upside down for the sake of a Shell, . . ."[137] He replied that it was vain to imagine that things remained the same, and that evidence and reason were allied with him against tradition.[138]

Few were willing to make the departures that Hooke had from the traditional world, especially when it meant the choice of some other means for the deposition of fossils than the Deluge of Noah. The important consideration was that they made such departures, and that they could do so because a major issue had been settled in the minds of many natural philosophers, and that was that fossils were organic remains. This resolution ennabled a person as Hooke to attempt to resolve the new questions that arose

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[137] Ibid. [138] Ibid., p. 450.

when an older question had been answered. It also freed other observers to do similarly. Several books and articles on fossils appeared which were primarily concerned not about whether such remains were organic or not, but rather with such heretofore subordinate questions as their location and their relation to each other.

This new feature in scientific opinion was evident in articles on this subject which were submitted in the closing years of this century and the beginning one of the next by Thomas Molyneux (1661-1703),[139] John Somner (fl. c. 1669),[140] John Luffkin (n.d.),[141] and John Wallis (1616-1703),[142] although some works did appear that were

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[139]Thomas Molyneux, "A Discourse Concerning the Large Horns, Frequently Found Under Ground in Ireland, Concluding from Them That the Great American Deer, Call'd a Moose, Was Formerly Common in That Island: With Remarks on Some Other Things Natural to That Country," Philosophical Transactions, XIX, No. 227 (For the Month of April, 1697), 489-512.

[140]William Somner , "Chartham News: On a Brief Relation of Some Strange Bones There Lately Digged Up, in Some Grounds of Mr John Sommer's in Canterbury," Philosophical Transactions, XXII, No. 272 (July, 1701), 882-93.

[141]John Luffkin, "Part of a Letter from Mr John Luffkin to the Publisher, Concerning Some Large Bones, Lately Found in a Gravel-pit, Near Colchester," Philosophical Transactions, XXII, No. 274 (For the Month of September, 1701), 924-26.

[142]John Wallis, "A Letter of Dr John Wallis, D. D. Professor of Geometry in the University of Oxford, and Fellows of the Royal Society in London, to Dr. Hans Sloane, Secretary to the Said Royal Society, Relating to That Isthmus, or Neck of Land, Which Is Supposed to Have Joyned England and France in Former Times, Where Now Is the Passage Between Dover and Calais," Philosophical Transactions,

chiefly devoted to the demonstration of fossils as organic remains.[143]

Molyneux discussed several discoveries of large horns excavated in Ireland. He was convinced that these were from some large creature, because of the size of one set of horns which were attached to a head, that was found.[144] Although no living representative of this creature was observed on that island, Molyneux was not able to believe that it had vanished, because

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XXII, No. 275 (For the Month of October, 1701), 967-77. See also John Wallis, "A Second Letter of Dr Wallis to the Publisher, Relating to Mr Somner's Treatise of Chartham News: and Some Magnetick Affairs," Philosophical Transactions, XXII, No. 276 (For the Months of November and December, 1701), 10[30]-1038.

[143]See Paolo Boccone, Mvseo di fisica e di esperienze variato, e decorato di osservazioni natvrali, note medicinali, e ragionamenti secondo i principij de moderni. Di don Pavlo Boccone, gentihuomo di Palermo, botanico del serenissimo gran duca di Toscana, Collega dell' Accademia Caesareo Leopoldina Naturae Curiosorum: ed al presente don Silvio Boccone monaco del Sacro Ordine Cisterciense della Provincia di Sicilia: con vna dissertazione dell' origine, (alla p. 262) e della prima impressione della prodizzioni marine, come fucus, coralline, zoophite, spongie, ed anche, interno l'origine de funghi, con figure in rame. E si trova in bottega di Giacomo Combi libraro in Merzaria, & in case del dottor Io Bohem medico tedisco a Santa Marina in Borgo all' Oco (Venetia: Io. Baptistam Zuccato, 1697), p. 181. Here Boccone, for example, argued that snake tongues (glossopetrae) were really petrified fish remains. The so-called eyes on these snakes were actually nothing but petrified amalgamations of fish eggs.

John Ray reviewed this book. See John Ray, "Museo di fisica & di esperienze, &c. By Signior Paolo Boccone, with Additional Remarks by Mr John Ray, F.R.S.," Philosophical Transactions, XXI, No. 249 (For the Month of February, 1699), 61-63.

[144]Molyneux, 289.

> --no real Species of Living Creatures is so utterly extinct, as to be lost entirely out of the World, since it was first Created, is the Opinion of many Naturalists; and 'tis grounded on so good a Principle of Providence taking Care in general of all its Animal Productions, that it deserves our Assent. However great Vicissitudes may be observed to attend the Works of Nature, as well as Humane Affairs, so that some entire Species of Animals, which have been formerly Common, nay even numerous in certain Countries; have, in Process of time, been so perfectly lost, as to become there utterly unknown; tho' at the same time it cannot be denyed, but the Kind has been carefully preserved in some other part of the World.[145]

Molyneux therefore knew generally what must have happened, and he had only to provide a reasonable background for this process. He concluded that the Deluge was not an adequate explanation for this animal's disappearance, for the bones would have crumbled in the waters, even if the doubtful assumption that the Flood was universal were granted.[146] Nor was an epidemic a satisfactory answer, because none of such a scale was imaginable.[147] Instead, it was likely that hunters had destroyed these huge animals, to feed the already large population of Ireland.[148] Next, Molyneux had to show that these animals were not extinct. After consulting various authorities, he decided that it was probable that they were the same animals as the West Indian Moose.[149]

Another example of excavated bones was soon thereafter

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145 Ibid.

146 Ibid., 499.

147 Ibid.

148 Ibid., 501.

149 Ibid., 503.

presented by John Somner. While digging a well for his house, he found at a depth of seventeen feet several bones, some whole, some broken, together with four petrified teeth, each of which teeth weighed over one-half pound. These teeth Somner presumed to be grinders.[150] They and the bones resembled, to him, those of a hippopotamus, and he decided that the constitution of the earth and the geographical arrangement of the surrounding terrain in which the bones laid confirmed his hypothesis that this was a marine--rather than a terrestrial creature.[151] Somner concluded with an elaboration of how the sea came to be in this region, and how this marine creature was buried so deep.[152]

Somner's account was widely read and provoked more investigations for and comments about subterranean bones. John Luffkin, for instance, remarked that upon reading Somner's article, he was moved to relate how he likewise had discovered a large bunch of bones, which were buried fifteen to sixteen feet deep near the village of Wrabness.[153] Luffkin, however, differed from Somner, in that he believed that these bones were those of elephants, rather than those of hippopotamuses. He cited ancient sources and a recent one to support his contention; of

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[150]Somner, 883.

[151]*Ibid.*, 884.

[152]*Ibid.*, 885-92.

[153]Luffkin, 924.

particular note was a Roman author's report which indicated that the Emperor Claudius (41-54) had brought elephants with him in his British campaign.[154] Luffkin also consulted a description of the anatomy of an elephant, which had been dissected in Dublin, and he thought that one of the bones that he had in his possession matched exactly a bone from that elephant.[155] Luffkin was convinced that the bones that he had unearthed were those of an elephant.

He believed that the bones and teeth that Somner had discussed were elephant remains, as well, for a number of reasons: the teeth in the latter's illustrations were the same as the molars of an elephant;[156] the village where the bones were found was on the invasion route used by Claudius's army;[157] and, finally, Somner's chief objection to the terrestrial animal origin of the bones was invalid. He had said that the bones had to be those of a sea animal, because only that could explain their deep location in the earth. Luffkin held that this was nonsense; earth could have been washed down over the elephants' bones by the flow of rain and melted snow from the adjacent hills, and grass, shrubs, and other vegetation, growing upon these remains, would have helped to cover them.[158]

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[154] _Ibid._

[155] _Ibid._

[156] _Ibid._, 926.

[157] _Ibid._, 924.

[158] _Ibid._, 926.

Another who read Somner's article was John Wallis. Wallis thought that Somner's hypotheses that the bones that he had found were those of a marine creature, and that the sea had covered the burial place of these bones, were essentially correct.[159] Wallis wrote that the probable reason for this inundation was that the sea had nowhere else to flow, because the present channel between England and France was blocked by an isthmus of land.[160] Moreover, Wallis added, this idea of the overflow of the sea was corroborated by the petrified bodies of fish and shell fish which were found in great depths in stone quarries and gravel pits.[161]

Wallis also read Luffkin's article. He admitted that the latter's views had some merit, but he remained unconvinced of their validity.[162] This was because the bones in both the places of Somner and of Luffkin were found in soil that had much gravel, as did the soil near Oxford, where the shell fish and fish were discovered.[163] Wallis considered this as further support for his belief in the isthmus.[164] Wallis concluded his comments with speculation upon the petrification process, which he believed was effected by petrifying steams. These either penetrated

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[159] John Wallis, "A Letter," 969. [160] Ibid.

[161] Ibid.

[162] John Wallis, "A Second Letter," 10[30]-31.

[163] Ibid., 1031. [164] Ibid., 1032.

the pores of bodies, or else encrusted their surfaces; in penetration they perhaps caused the bodies to swell and appear larger, as wood did when it imbibed water.[165]

All of these latter writings gave only a surface indication of the great change in the thinking about fossils that had occurred in the minds of many natural philosophers. The replacement of the inorganic theory by the organic unleashed new modes of thought that could not have been characterized in the older ways of observing nature. Martin Lister simply could not have speculated about Somner's excavations as Luffkin did; Lister's thinking, instead, would have been more attuned to Kircher's thoughts about similar phenomena unearthed years earlier. What happened, then, in the fossil controversy, was not its death because of its apparent resolution, but rather its involvement in a host of new questions. One of the most important of these questions was the manner of its incorporation into the traditional scriptural interpretation of history.

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[165] Ibid., 1031.

CHAPTER IV

FOSSILS AND EARTH HISTORY

The inferences drawn from the study of fossils in the latter half of the seventeenth century were largely determined, as they would have been in any other age, by the presuppositions which lay within the minds of the natural philosophers who pursued that topic. At that time, there were certain fundamental ways of looking at nature which greatly affected all explanations of natural phenomena; the study of fossils was especially so influenced. These outlooks were largely theological in nature, although it was nearly impossible to isolate the religious influences within the minds of one or of many investigators, so strongly did these influences color all of the aspects of the lives of all of these men.

Basically, the predetermined ideas with theological connections which were consciously or unconsciously incorporated within speculation about fossils, included the following: the world was created by an omniscient God as a habitat for mankind; the story of this world was the story of what had happened to man's home; man was almost as old as his earth, and the great events of human and natural history--the creation, the Deluge, and the future end of the world--were simultaneous; these joint histories were brief--about six thousand years in duration; and they were both regulated by a God Who had taken special care to preserve all of His creations, and, yet, Who had allowed His world to enter into a state of decline from its original perfection as a part of His punishment to man for man's successive sins. The task of the natural philosopher within this scheme was to show that natural history agreed with theological revelation.

Once fossil remains came to be regarded by a number of scientists as remnants of organic creatures and things, many questions required new solutions. Two were important: what determined the location of these fossils? Why did some of these fossils have no living counterparts? Many by 1700 answered these queries, respectively, by saying that the shells and the other remains had been deposited where they were now found by the Deluge of Noah, and that all fossils had representatives among living creatures, because Providence would not suffer any of its species to disappear. It is important to remember that these solutions, despite the assertions of later historians, were probably not primarily the result of any extreme religious reactions which had been afoot since the Reformation,[1] but instead

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[1]For examples of this view see Francis C. Haber,

that they probably were, to the contemporary writers concerned, the most reasonable and agreeable manner of describing the history of a deeply religious world, from which the influences of Rene Descartes (1596-1650), Sir Isaac Newton (1642-1727), and others, had not yet completely removed the regularly intervening Hand of God. In short, there was no general conflict between religion and science in this instance as many have supposed, but there existed, rather, a basic agreement between the two.

One indication of this agreement was that a large number of theologians, some of whom were eminent in their churches, were among the writers upon the subject of fossils. One of the first of these authors in this period was Nicolaus Steno (1638-1686). Steno, a Dane, studied at the universities at Copenhagen, at Amsterdam, at Leyden, and at Paris. After his formal education, he moved to Florence, where his renown in science gained him the patronage of the Grand Duke of Tuscany. Later Steno converted to Catholicism, took holy orders, and became deeply concerned with religious affairs.[2]

The Age of the World: Moses to Darwin (Baltimore: The Johns Hopkins Press, 1959), pp. 50-51; Archibald Geikie, The Founders of Geology (2d ed.; London: Macmillan and Co., Limited, 1905), pp. 54, 60; Frank Dawson Adams, The Birth and Development of the Geological Sciences (Baltimore: The Williams & Wilkins Company, 1938), p. 262; and Andrew Dickson White, A History of the Warfare of Science with Theology in Christendom (2 vols.; New York: D. Appleton and Company, 1908), I, 217-19.

[2]Geikie, pp. 53-54, and Nicolaus Steno, Nicolai

Before Steno devoted himself entirely to religion, he wrote two works in which he discussed fossils, the first of which was his Myologiae Specimen.[3] This book was principally a work about anatomy, but Steno included within it an appendix in which he discussed his dissection of the head of a giant shark which had been caught off the coast of Tuscany and which had been sent to him in Florence. Steno saw a great resemblance between the teeth of this shark and the so-called *glossopetrae*, or tongue-stones, which were found in great numbers upon the island of Malta, and he came to believe, as Colonna had before him, that *glossopetrae* were nothing more than the petrified teeth of sharks.[4]

With this generalization in mind, Steno drew from his general studies about the fossil problem a number of observations, which he wrote that he had confirmed with his own eyes.[5] He noted that, for example, the soil from

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Stenonis opera philosophica, ed. Vilhelm Maar (2 vols.; Copenhagen: Vilhelm Tryde, 1930), I, i-xi.

[3]Nicolaus Steno, *Nicolai Stenonis elementorvm myologiae specimen, sev musculi descriptio geometrica. Cvi accedvnt canis carchariae dissectvm capvt, et dissectvs piscis ex canvm genere* (Florentiae: ex typographia sub signo stellae, 1667). An English translation of a portion of this work is available. See Nicolaus Steno, *Nicolaus Steno (Niels Stensen), The Earliest Geological Treaties (1667)*, trans. from *Canis carchariae dissectum caput*, with introd. and notes by Axel Garboe (New York: St. Martin's Press, 1958).

[4]Steno, *Myologiae specimen*, pp. 69-72, 109-10.

[5]*Ibid.*, p. 115.

which the marine-like bodies were dug was as hard as stone in some locations, and as soft as clay or sand in others. This soil, whether hard or soft, was always compact and composed of layers, one atop the other, which lay in an oblique angle to the earth's horizon. Among soils, clay had layers that differed from each other in color and that were split apart in many places, and that its fissures were filled with single-colored substances that lay at right angles to the layers themselves. The same soil often had bodies of both a hard and a soft composition. In clay soil, these bodies were plentiful upon the surface of the soil and scarce beneath it. The bodies that were found in clay were all very fragile and could all be easily crumbled into a whitish powder, and their fragility increased as one dug deeper into the clay. Bodies were more numerous in rocks in which they were found throughout to be of the same consistency. Bodies were attached to the rock as though they were embedded in lime or gypsum. The bodies that had forms similar to those of marine creatures, whether they were dug from hard or soft soil, were like each other and also were like the parts of the living animals to which they corresponded, as there was no difference in the pattern of the stripes, in the structure of the lamellae, in the turnings and protrusions of the cavities, and in the joints and hinges of the mussel shells. The same bodies could be as hard as stone, or so soft that they could be pulverized with facility. Bodies were found in all manner of combinations and conditions--oyster shells were found mis-shapen and molded together into a solid mass, broken and whole shells of scallops and snails were excavated, and many stone-tôngues, some large, some small, were discovered embedded together in the same matrix. From these observations, Steno believed that he could obtain six valid conjectures.[6]

First, Steno began, the soil from which were dug the bodies that had shapes like parts of animals had not produced those bodies in the past.[7] This was true in either soft or hard soil. In the former, the deeper one dug, the more fragile the bodies became, which indicated that the soil destroyed them, and not that they were soft because they were plants, growing in size and increasing in numbers. Live young plants were held together by an adhesive matter which these substances did not have, and the apparent increase of these substances was due to rain, which washed away the soil and exposed more shells, and which incidentally thus saved more shells from destruction by the soil.[8]

Nor did the soil produce those bodies in Steno's time. Shells found in hard rock had a uniform consistency,

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[6] *Ibid.*, pp. 91-93.

[7] *Ibid.*, p. 93.

[8] *Ibid.*, pp. 93-94.

showed no differences from the bodies produced in the past, and left no signs of pressure against the rocks in which they were embedded. All of these observations indicated that they did not grow in the soil.[9]

Second, the soil in which the bodies were produced was not firm at the time of their production. Those bodies, whether from soft ground, from rocks, or from animals, were always of the same shape. Since they had not developed in the ground, and since they would have been deformed if they had grown in hard soil, as the roots of trees were, the soil must have been soft when they were produced.[10]

Third, the ground in which these bodies were found was once covered with waters. This was accomplished in one of two ways: either by a great flood, in which the waters at the Creation and at the Deluge had inundated the land, or by a movement of the land.[11] Either course was probable, as arguments could be marshalled for both. In the first instance, some held that the bodies ought to be found everywhere and not only in high places, if the Flood were universal; since they were not, it was not. These people were wrong, Steno said, because the water did not carry the shells everywhere, and because the

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[9]*Ibid.*, p. 94. [10]*Ibid.*, pp. 94-95.

[11]*Ibid.*, p. 95.

shells on the tops of mountains were bared by rains, while those in the lowlands were covered.[12] In the second instance, fissures filled with a substance of one color, while the layers beside the fissures were composed of many colors, were factual testimony that the ground had been shaken by a violent motion. There were many records of upheavals, such as earthquakes, that could have effected such a shift in position. Probably both examples were correct, in that the ground had not only been shaken by earthquakes, but that its softness revealed that it had also been flooded.[13]

Fourth, the soil where these bodies were found was once mixed with water. Observation revealed that clay and sand traveled in streams, either in powdered form, or as elements, and that wind mixed with these soils agitated water.[14] Other substances, and living creatures as well, combined with waters. Even limestone could be dissolved in waters, which made this hypothesis easy to believe.[15]

Fifth, the soil with the bodies in it came from gradual sedimentation from water, as was shown by the different layers of soil which were distinguishable by their colors. The waters in ages past had washed away particles of soil, some of which had settled to the

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[12] Ibid., pp. 95-96.

[13] Ibid., pp. 96-97.

[14] Ibid., p. 97.

[15] Ibid., pp. 97-99.

bottom--the heavier particles first, the lighter ones last. The air had also left earth and animals in the waters, and these, too, were laid down in layers on the bottom of the waters.[16] This penetration of the particles of the fluid, water, by the particles of other substances, and the precipitation of the particles of the other substances, were all readily explainable according to certain principles.[17]

Sixth, and last, bodies dug from the ground which were shaped like parts of animals, ought to be considered as parts of animals. The soil, formerly soft and mixed with waters, did not produce them, and it seemed likely that, because of their location, these bodies had once been the remains of animals which had died in the waters, and which had been deposited into layers with the other sedimentation from the water.[18] The animals probably settled in terms of generations; the oldest died and mixed with other matter, and the younger ones later died and joined newer sediment. Their remains survived because crustaceans, the type of shell fish most often found, had durable shells, lived in caves where they were not exposed to the destructive force of agitated waters, and did not prey upon their own kind.[19]

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[16] Ibid., pp. 99-100.

[17] Ibid., pp. 100-104.

[18] Ibid., pp. 104-05.

[19] Ibid., p. 105.

It was certain, Steno continued, that this comparison of shell fossils with living shell fish could be made, because the fossils were the remains of living creatures, both in form and in substance. The form was similar for several reasons: they appeared to be the same in shape; fossils had not many more irregularities than crystals, which they should have had, if they were mere imitations by nature of a bulky composite form; masses of fossil oysters were found together, just as living ones were in the ocean; fractures were observed in fossil snail shells and not in real ones, but the broken parts were usually found nearby; tongue-stones of different sizes and compositions were discovered stuck together, just as they were found, arranged in rows, inside the mouths of freshly-caught sharks; and the defects found in the complex bodies of the petrified shells were few, and these defects were the same as those in the shells of living animals.[20] They were similar in substance, as well, as experiments in chemistry abundantly confirmed. The heavier weight of petrified shells as opposed to live shells, for example, was a product of a chemical process to which all animals were subject. All substances in shell animals were either reducible to a powder or to a juice according to particular procedures; fossils reacted

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[20]*Ibid.*, pp. 106-07.

similarly to these procedures.[21] Hence fossil shells were like shells of living fish in both form and substance.

Steno thus had held that all fossil shells were the remains of living shells, and he chose, as an example, the stones known as glossopetrae on the island of Malta, which he believed were the petrified teeth of sharks. Steno hypothesized that Malta was at one time barely submerged and that sharks bred in the shallow, muddy waters. Later the island rose by an ignition of subterranean effluences and left many glossopetrae--so many, in fact, that some said that these must be inorganic productions, for sharks did not grow teeth in such quantities, to which Steno replied that some sharks had over two hundred teeth, and that they grew new ones every day.[22] Steno concluded, therefore, that the glossopetrae were the petrified teeth of sharks because of their shape and because of their numbers and position.[23]

In his initial effort, Steno had presented in a lucid and concise form many of the arguments that those who believed that fossils were organic productions of nature had used and were to use. He had studied, in addition, the animal and plant life that both marine and fresh water contained, and he believed that this life was

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[21] Ibid., pp. 107-09. [22] Ibid., pp. 109-10.

[23] Ibid., p. 110.

deposited as sediments into horizontal strata. He also had speculated that later upheavals had moved the strata from their original positions, had discussed the power of juices that operated within the earth, and had compared certain of the workings of nature with operations that could be duplicated in a chemical laboratory. He had confirmed all of these investigations and hypotheses, he wrote, from visual evidence.[24]

The fundamental ideas for Steno's hypotheses about the formation of fossils were not original. It was in the elaboration of these bases that Steno displayed his genius, especially in his discussion of the deposition of these fossils within the earth. Steno also had a talent for the presentation of his ideas.

Steno's second contribution to the study of fossils was his De solido.[25] In this book, Steno resumed his

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[24] Ibid., p. 115.

[25] Nicolaus Steno, Nicolai Stenonis de solido intra solidvm natvraliter contento dissertationis prodromvs (Florentiae: ex typographia sub signo stellae, 1669). A recent English translation is Nicolaus Steno, The Prodromus of Nicolaus Steno's Dissertation Concerning a Solid Body Enclosed by Process of Nature Within a Solid, trans., with explanatory notes, John Garrett Winter. Foreward William H. Hobbs ("University of Michigan Studies: Humanistic Series, Contributions to the History of Science," Vol. XI, Pt. 2; New York: The Macmillan Company, 1916). An early English translation is Nicolaus Steno, The Prodromus to a Dissertation Concerning Solids Naturally Contained Within Solids Laying a Foundation for the Rendering a Rational Accompt Both of the Frame and the Several Changes of the Masse of the Earth, as Also of the Various Productions in the Same, trans. H. enry O. ldenburg

studies which he had initiated by his investigations about the teeth of sharks, and he extended these studies to include shells and other remains that he believed to be organic.[26] Steno held that the organic origin of fossils was a necessity because, if proven correct, it would enable him to resolve several difficulties of natural history with a high degree of certitude.[27]

He noted, however, that many other contemporary natural philosophers thought that fossils were the products of the action of an unknown force in nature.[28] These people attacked those of the ancient philosophers who had believed that fossils were dead marine animals, and who had been troubled by only one problem in this matter--the reason for the location of the marine bodies so far from land.[29] The ancients had never bothered to inquire whether such animals could have been produced upon the land, as well. Consequently their opinions were later rejected by many who denied that the sea had ever covered the land

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(London: J. Winter, 1671). This early translation was reviewed. See [Anon.], "The Prodromus of a Dissertation Concerning a Solid Contained in a Solid, by Nicolaus Steno. English't out of Latin," _Philosophical Transactions: Giving Some Accompt of the Present Undertakings, Studies and Labours. Of the Ingenious in Many Considerable Parts of the World_, VI, No. 72 (June 19, 1671), 2186-90. Cited hereafter as _Philosophical Transactions_.

[26] Steno, _De solido_, p. 2.

[27] _Ibid._, p. 7.

[28] _Ibid._

[29] _Ibid._

where these marine remains were.[30]

There were two other current opinions about the origin of fossils, Steno continued, that were of some importance. The first was that of the ancients; its modern adherents had proved, he declared, that marine-like fossils had come from no other place than the sea.[31] The second was a compromise; its disciples considered part of the fossils to have been of the land and part of the sea.[32]

Steno remarked that he had accepted neither of these opinions, nor any other, as true. Instead, he had probed his mind with matters that concerned his research, especially about such vague topics as an immemorial succession of years and a number of floods, and about more specific subjects, such as the ideas of other authors and the objections of his friends. He proceeded with this scrutiny until he had reduced the fossil problem to a few questions for which he thought that he was able to supply reasonable and simple solutions.[33] As he wrote:

> Prima quaestio erat, an Glossopetrae Melitensis Canum Marinorum olim dentes fuerint, quam illico eamdem esse patuit cum quaestione generali, an marinis corporibus similia corpora, que procul a mari reperiuntur in mari olim producta fuerint; cum vero in terris etiam reperiantur alia corpora illis similia, quae im aquis dulcibus, aere, alijsque fluidis crescunt, si damus terrae vim producendi haec corpora, non possumus detrahere illi facultatem

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[30] Ibid.

[31] Ibid.

[32] Ibid.

[33] Ibid., pp. 7-8.

reliqua generandi; oportuit itaque quaestionem extendere ad omnia illa corpora, que e terris eruta, similia deprehenduntur illis corporibus, quae, alia in fluido crescere videmus, sed & multa alia in saxis reperiuntur certa figura predita, quae si quis loci vi producta dixerit, eadem vi producta reliqua omnia admittat necesse est, adeoque eo tandem deductam rem vidi, vt quod libet solidum solido naturaliter inclusum examinandum esset, an, quo loco reperitur in eodem productum fuerit, id est, examinandem esse naturam, tum loci vubi reperitur, tum loci, in quo productum est, at vero locum productionis nemo facile determinauerit, qui productionis modum ignorat, & de productionis modo vana est omnis dissertatio, nisi de materia natura certam quamdam cognitionem habuerimus; vnde patet, quot resoluendae sint quaestiones, vt vnicae quaestioni fiat satis.[34]

All these questions Steno claimed to be able to

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[34]Ibid., pp. 8-9. The first question was if the glossopetrae melitensis were at one time the teeth of sharks; this question seemed immediately to be the same as the general question of whether bodies that resemble marine bodies, and that are found far from sea, were produced in the sea. But because other bodies are found on land which resemble those that grow in fresh water, in the air, and in other fluids, we cannot deny the possibility of the earth producing these bodies, if we grant it has the power to make the others. It was necessary, therefore, to extend the study to encompass all those bodies which are excavated from the earth and which are observed to be similar to those bodies which are seen growing in fluids in other places. Other bodies, however, are found in the rocks which have particular forms, and if one says that they were there reproduced by the action of a force, one must also admit that all the other bodies were produced by the same force. In this manner the question finally reached the period where any certain solid contained within a solid must be examined in order to determine if it was produced in the very place where it was found. Therefore, both the character of the place of production and the place itself must be examined. No one can, though, truly determine the place of production unless he also knows the manner of production, and no discussion about this could be worthwhile until some valid knowledge concerning the nature of the matter is obtained. From this it is obvious how many questions have to be resolved so that a lone question may be set at rest.

resolve according to fundamental laws of nature that were common to all schools of philosophy.[35]

Accordingly, Steno dismissed as tautological the idea that fossils were produced by the action of the agents of nature. The particles of Nature's productions, he wrote, received their motion from the action of a penetrating fluid, whether this fluid came from the sun, from fire within the earth, or from a soul. As the causes of these agencies were unknown to man, he who attributed the production of anything in nature to such an agency, or to Nature itself, attributed the production to something known only by name. Furthermore, since place and matter were necessary to understand production, it was obvious that not only was that answer more mysterious than the question, but that it was also incomplete.[36] Mollusks found on land and in the sea could both, for example, be attributed to Nature. Nature did produce all things, as the penetrating fluid. The fluid by itself, however, did nothing, because its determination depended upon the place and matter to be moved, just as man could produce everything, but only if he had the means.[37]

Thus he who attributed to the earth the production of anything named the place and no more, because the earth,

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[35] <u>Ibid.</u>, pp. 9-10.

[36] <u>Ibid.</u>, pp. 13-14.

[37] <u>Ibid.</u>, p. 14.

at least partially, was the place of production of everything. The same case could be made for Nature: those things formed in the earth were all produced by the earth; none of those things formed in the earth was produced by the earth.[38] Hence no conclusion was obtained with that conclusion.

Steno rejected this opinion in favor of the organic production of fossils. He believed that

> 3. Corpora illa, quae e terris eruuntur, plantarum, animaliumque partibus per omnia similia, eodem modo, & loco, producta esse, quo modo, & loco productae sunt ipsae plantarum, & animalium partes.[39]

To confirm this theory to himself Steno made lengthy investigations, and from these studies he chose the mollusks to examine in detail.[40] Of these shells, he compared both those taken from the seas and those taken from the mountains, because he was convinced that there was a connection between the two.

Living sea shells, he found, had several unique physical characteristics. The whole shells were divided into subdivisions, and the subdivisions into filaments. The filaments were of two kinds, distinguishable from

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[38]Ibid., p. 15.

[39]Ibid., p. 17. Those bodies which are dug from the earth and which are in every way similar to the parts of plants and animals, were produced exactly in the same way and in the same place as the parts of the plants and animals themselves were produced.

[40]Ibid., pp. 2-3, 16-17, 24-25.

each other by color, composition, and place. Within the subdivisions the upper and lower surfaces of the shells were nothing but the ends of filaments, while the surface of the edge of the shell was a combination of the sides of the filaments seen in the edge of the subdivision. The inner surface of the shells was the same as the inner surface of the deepest and largest subdivision, and the outer surface was the outer surface of the smallest subdivision and an aggregation of the surfaces of all of the edges of the intermediate subdivision.[41]

Steno also thought that these living shells had a number of paramount aspects in regard to their formation, all of which could easily be proved to exist: the substance of the filaments was a fluid that came through the outer surface of the animal, similar to sweat; the form of the filaments was made either in the pores of the animals or on the surface of the growing animal, where it drew the viscous fluid located between the subdivisions into filaments, aided by the fresh excretions from the pores; a difference in the filaments could be obtained by investigations of the dissimilarity of the pores on the surface of the animal and of the two substances that came through the pores. Both substances were fibrous, but one was soft, the other hard; and all of the subdivisions, except the

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[41]Ibid., pp. 52-53.

smallest, obtained their shapes from their location, as they were produced between the body of the animal and the outer shell. The outer shell itself was probably not surrounded by a fluid, for it was protected by a membrane, a correct observation both because the filaments of the remainder of the subdivisions were all untouched by the surrounding fluid when they were formed, and because there were living shells, such as the prickly cockles, that had something akin to a skin cover or membrane over the outside of their shells.[42] All of these aspects, Steno implied, were obvious to unbiased observers, and he believed that his observations enabled him to easily explain otherwise incomprehensible phenomena, such as the diversity of hues and spines in buried shells and the formation of pearls, and to attempt a division of the inland shells into three classes.[43]

The first of these classes of shells which were found within the earth was that of those shells that were similar to living sea shells in all physical respects. Examinations of these shells verified, Steno held, two conclusions: that they were once occupied by living animals and that they were surrounded by a fluid.[44] Employing bivalvular mussel shells as examples, Steno put

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[42] Ibid., pp. 53-55. [43] Ibid., pp. 55-57.

[44] Ibid., p. 57.

forward a number of reasons for these conclusions. A mussel had: a smooth surface with pores of a twofold variation; a substance more soft and pliable than the shell; a union with the surrounding matter on one side and not on the other; a tendency to mass on the side where it had communication with the outside matter; an ability to open itself in proportion to the size of its hinges; a faculty to grow to a large shell; and an aptitude to send through itself the matter of which its subdivisions were constructed.[45] The matter around a mussel was, if not a fluid, at least less resistant than the inherent power of expansion within the shells, and it also contained a fluid conducive to the formation of the filaments of the subdivisions of the shells. These conditions outside of and inside of the mussel shells confirmed to Steno his ideas.[46]

The second class was that of those shells which were like living shells in all physical respects except color and weight. The heavier ones of these had absorbed an extraneous fluid through their pores, and the lighter ones had lost some of their interior parts. All of these shells were only the petrified or calcined shells of dead animals.[47]

The third and last class of shells were those which

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[45] Ibid., pp. 57-58.

[46] Ibid., p. 58.

[47] Ibid., p. 58.

resembled living shells only in form. They had neither subdivisions nor filaments and were filled with such diverse substances as crystal and marble. These shells had been penetrated after the death of the animal inside by a fluid which then dissolved. This either left empty spaces or else it was replaced by another substance.[48]

There were other shells, besides mussels, which Steno had observed and which he believed to be of organic origin, such as a mussel with a pearl, a large pinna, a shell partially filled with marble, minute eggs, small round shells, pectens, and other remains.[49] Steno considered some very large oyster shells as the most important of these. They had long cavities in them that had been hollowed out by worms. These, Steno concluded, were what they seemed to have been indicated to be by observation, as all the cavities had both an entrance and an exit, and all appeared to have been eaten out section by section. This would have required a gnawing action, of which mussels or a penetrating fluid would have been incapable. Hence, to Steno, there must have been worms in these tunnels at one time.[50]

Steno believed that as an organic origin was true for excavated shells, it was also true for the remains of

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[48] Ibid., pp. 58-59. [49] Ibid., pp. 59-61.

[50] Ibid., p. 60.

animals which were, either in whole or in part, dug up from the earth. The animal relics, as were the shells, were comparable to their living counterparts in one of three ways: they were exactly physically alike them; they differed from them only in weight and color; or they were alike them only in external shape. These terrestrial remains, besides horns, teeth, femurs, crania, and other bones of land animals, also included remains of fish, as whole fish of all varieties, and the teeth of eagle fish and sharks.[51]

Steno was particularly interested in the latter teeth, both because he found a great number of them upon the island of Malta, and because he felt that they constituted a good example to use as support of his belief that these teeth and other similar remains were of organic origin. Some had argued, for example, that the great number of teeth on the island was an indication of their inorganic origin, as there were too many of them to be the remains of marine animals. Steno had thus only to offer suitable arguments as to why such a large number were the remains of sharks, which he did with several ideas: each shark had six hundred or more teeth, and each seemed to grow new ones constantly; the sea tended to heap shark bodies together in particular places; sharks

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[51] *Ibid.*, p. 61.

traveled in schools and so left their teeth in the same locations; and other marine remains were found as well upon Malta, including mollusks and other sea beings.[52]

One difficulty, however, to Steno's explanation of these excavated phenomena as of organic origin was the extraordinary size of some of the animal-like remains. Many observers were unwilling to ascribe to the belief that these bones were once-living creatures, because they accepted the prevalent opinion that these bones were sports of nature. In addition, they had no credence in, as Hooke later did, any view of nature that permitted an alteration of species and a time scale greater than that of the traditional six thousand years that was usually thought of as a necessary corollary to such an extension. Steno attempted to allay both objections with the assumption that these remains were the bones of giants, as bodies of very tall men were found in his own day; as it was certain that giants lived at one time; as many frequently mistook animal for human bones; and as nature, perfect in its operations, would not have produced such bones as were discovered, unless it had also produced the rest of the man as well.[53]

Steno concluded his remarks about the organic origin of now-dead living things with the idea that his opinions about animals were equally applicable to

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[52] Ibid., pp. 61-62. [53] Ibid., p. 62.

plant-like objects. These he divided, as he had the animal remains, into three classes: the rarest, or those that were physically like living plants; those that differed from actual plants only in color and weight; and the most abundant, or those that were alike existing plants only in form.[54] Each class he examined in turn.

Steno believed that observation confirmed beyond any possible doubt that the first two classes were once living plants. Both the structure of their bodies and the type of place from which they came, he held, supported this view. He noted, however, that some thought that these subterranean plants were actually formed from earths by a process of nature which operated over a long period of time. Steno dismissed this idea as nonsense, and he declared that the wood found within earths was that which was buried with those earths. When the earths dried, the wood inside them appeared.[55] Moreover, mineral matter found within excavated wood was no refutation of his opinion, he continued, because he himself had dug up a tree trunk in which he had seen minerals inside of its fissures. Yet this trunk was unmistakably a plant, as both the knots on its branches and its bark affirmed.[56]

The confirmation of the third class, or the forms

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[54] *Ibid.*, p. 65. [55] *Ibid.*

[56] *Ibid.*, pp. 65-66.

of plants seen upon stones, as of organic origin, posed a more difficult problem for Steno. This was due to similar forms observable upon frost, in mercury crystals, in volatile salts, and in glasses which contained a white solution. Actually, Steno thought this situation was not one of confusion, for he reduced the plant forms to two kinds: those only on the top of stone divisions and those which were not only on the surfaces, but which spread their branches throughout the stone.[57] The first kind was produced by a fluid which merely touched a plant. The second was made either when it was engulfed by a fluid, or else when the plant grew into a stone that had not yet lost the character of a fluid. The soft texture of the stone showed this, and so did the angular bodies, formed only in a free fluid, which were found on the dendrites of Elba. This was also demonstrated by experience, Steno related; in many moist places he had noticed that the action of water was petrifying moss, while at the same time new moss was growing upon the petrifications.[58]

Steno thus completed one phase of his arguments. In this phase, he believed that he had convincingly demonstrated from experience and reason that all of the terrestrial and aquatic animal-like remains, as well as the plant-like bodies, were of organic origin. A review of

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[57]*Ibid*., p. 66. [58]*Ibid*., pp. 66-67.

his procedures, however, indicated that he had relied not so much upon observational experience as he had upon his own persuasive reason. The evidence he put forth was old; only his method of consideration of it was unique:

> Hactenus precipua illa corpora recensui, quorum locus, in quo reperiuntur, multis dubium reddidit locum productionis eorumden; & eadem occasione subindicani, quomodo de eo, quod insensibile est, certum quid ex sensibili concluditur.[59]

This type of argument was also applicable to the other areas of Steno's thoughts, and he proceeded to use his conclusions about perceptible fossils to the shaping of an otherwise imperceptible earth history. Fossils, as solids contained within solids, were thus the basis of his arguments, and as such were the most important factors in his further speculations:

> Secunda parte resoluitur problema vniuersale, vnde singularum difficultatum enodatio dependet, quod est; <u>dato corpore certa figura praedito, & iuxta leges Naturae producto, in ipso corpore argumenta inuenire, locum, & modum productionis detegentia.</u> Hic, antequam problematis resolutionem enoluendam aggrediar, omnia eius verba eo sensu exponere allaboro, vt nulli Sectae Phylosophorum dubium quid in illis, & controversum relinquatur.[60]

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[59] Ibid., p. 67. Until now I have reviewed the principal bodies whose location has given to many people no idea of the place of their production; and meanwhile I have indicated how, from that which is perceptible, one can form a certain conclusion about that which is imperceptible.

[60] Ibid., pp. 5-6. In the second part a universal problem is resolved, upon which the unfolding of each difficulty depends, and it is: <u>given a substance of a certain figure which is produced in agreement with the laws of nature, to find arguments in the substance itself</u>

Fossils aided Steno greatly in the resolution of this problem. Produced in the past as they were today, fossils were found embedded in regular, even layers of strata, much as those layers of mud that turbid waters had deposited. These layers of fossils suggested to Steno a history of the earth's crust. He decided that the layers, or strata, of the earth's crust had been deposited as fluids because of the fossils that were seen within these strata. These strata, he proceeded, had been deposited in successive layers, the lowest first and the highest last, and each layer had been extended evenly as far as the geography of the surrounding terrain had permitted.[61] The contents within these layers, for Steno, supported his belief in a regularity of their deposition, and they also showed what had caused these strata. The stratum laid down at the creation, for example, had fine particles of a character similar to each other, and it was undeniably produced from a fluid which at that time had covered all of the earth. Strata which had pieces from another stratum, or parts of plants and animals, had been deposited after the first stratum. Strata which

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which detail the place and manner of its production. In this vein, before I continue to develop the resolution of the problem, I shall try to elaborate all of its terms in order to leave no sect of philosophers in doubt and in controversy about them.

[61] *Ibid.*, pp. 26-28.

contained sea salt, the remains of marine animals, the wreckage of ships, and other objects similar to those which were found upon the floor of the ocean, once had been under the sea, an event that was caused by either a flood or by an eruption of the mountains. Stratum with a large amount of grasses, rushes, pine cones, branches and trunks of trees, and other like substances, had acquired this matter from either river or rain floods.[62] The contents of other strata indicated the locations and method of their formation in like manner.[63]

The strata, however, had not remained in their original horizontal positions, but some had since crumbled, broken, and shifted into other places relative to the horizon. The strata had been formed in fluids, and each had had solid material both beneath and on its sides, except for those strata which had enveloped the earth. The upper surfaces of the strata, then, were all at one time level because of their initially fluid character.[64] The current altered position and exposed sides of some of these strata did not alter this conclusion; it merely indicated that some changes had occurred--changes which were evident in low plains, high plains, valleys, lakes high above the sea, mountains, and other such prominent

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[62] *Ibid.*, p. 28.

[63] *Ibid.*, pp. 28-29.

[64] *Ibid.*, pp. 29-31.

landscape features.[65] These alterations had been brought about, Steno conjectured, by incipient violent upthrusts of the upper strata that were caused by the ignition of subterranean gases. These upheavals thereby formed mountains.[66] The upper strata were next undermined and began to slip, for the lower strata which supported them were eroded away by both underground fires and by torrents of water.[67] The upper strata finally collapsed and formed a valley. The edges of the strata were exposed on the sides of the valley at the point where they had ruptured. The waste pieces of the strata that had collapsed became material that constituted a second type of hills and mountains which, though they were smaller than the other type of eminences, were augmented in size by erosion, brought about by waters, from larger mountains nearby.[68] Steno consequently concluded that it was possible to draw a history of the earth from the study of the hills, valleys, and other features of the terrain, as he had. He noted:

> Posse euerti montes, transferri agros ex vuo latere in alterum per mediam viam publicam; eleuari, & deprimi cacumina montium; aperiri terras, iterumque daudi; & id generis alia contingere, quae in historiarum lectione pro fabulis habent, qui creduli nomen evitare student.[69]

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[65] _Ibid._, pp. 31-32.

[66] _Ibid._, p. 31.

[67] _Ibid._, pp. 31-32.

[68] _Ibid._, pp. 32-33.

[69] _Ibid._, p. 34. It is possible that mountains can be overturned, and that fields can be transferred from one side of a high road over to another; that summits of

Tuscany was to Steno a perfect example of his hypothesis that the past conditions of any thing were evident in its present condition. The surface inequalities that he examined there were all manifest indications of changes.[70] He divided these alterations into six distinct periods--two fluid, two level and dry, and two broken. At the onset of time, Tuscany was completely covered with water. The water, aided by fires, hollowed out huge caverns beneath the upper strata, which then collapsed and formed valleys and mountains. The water next covered the lower terrain and deposited upon it a new sandy strata. The lower portion of the new strata was itself undermined, and later broke and formed new hills and valleys. This erosion and strata deposition, and other processes of nature, continued until all of the present features of modern Tuscany, such as its swamps and sunken plains, appeared.[71] Although Steno left many difficulties in his scheme unresolved, such as the question of what had happened to the great amount of water he required, he remarked with strong conviction that he had proved his hypotheses by

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mountains can be elevated and depressed; that the earth can be opened and closed; and that other things of this type can happen which in the reading of history of those who do not wish to be styled credulous, have been considered as fables.

[70]Ibid., p. 67.

[71]Ibid., pp. 67-69. See also plate VI opposite p. 76.

reference to the Tuscan scene and that he had confirmed them with references to the entire earth drawn from separate authors.[72]

Despite his assurance, Steno called upon Scripture to confirm what he considered as his own advanced views, so that these views might not prove too novel for others.[73] He found, not surprisingly, that Scripture either agreed with his own presentation of history or, that if it did not concur, that it did not explicitly disagree. Scripture often, Steno noted, buttressed his hypotheses when nature did not; Scripture, not nature, spoke in detail of the beginning age when the earth was covered with waters and of the second period when the earth was level and dry.[74] Steno believed, however, that nature and Scripture normally agreed. The presence of strata in the highest mountains, which by their form indicated a former presence of a fluid and which by their composition implied a lack of organic bodies within them, confirmed that there were waters before the existence of plants and animals, and also showed that these waters had covered the entire earth. Moreover, the unmixed matter of these same strata was, with their form, of a marked likeness to the matter and form of numerous other similarly-placed strata, regardless of the distance

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[72] Ibid., p. 69. [73] Ibid.

[74] Ibid., pp. 69-70.

apart or of the differences of the mountains in which these strata were located. Nature and Scripture, in addition, each attested to a great flood that had covered the earth after the rise of the land, and profane history concurred with both sources in this matter. There were cities in Tuscany that were over three thousand years old which had been built upon hills formed by the sea, and there were like cities in Lydia that were nearly four thousand years old. Both groups of cities were thus built shortly after the Biblical Deluge of Noah.[75] The events after the Biblical Flood, though, were not explicit in either secular or sacred history. The recession of the waters, the emergence of huge plains, and the reconstruction of these plains into the hills, the valleys, and the other features of modern times, were only known, according to Steno, through the study of natural phenomena.[76]

Steno explained these changes with a reliance upon the actions of natural forces which operated in a uniform manner, and he thought that such alterations as had occurred in nature were readily tracible to these powers. To support his contentions, he reasoned in a negative fashion why no documents supported his claims:

> nec mirandum est, apud historicos non legi, quo tempore quaelibet mutatio contigerit. Primorum enim a diluvio seculorum confusa est & dubia historia apud profanos, labentibus vero seculis illustrium virorum

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[75] Ibid., pp. 69-74. [76] Ibid., pp. 70-75.

> facta, non autem Nature miracula celebranda sibi sumpserunt. Desideramus nihilominus citata Scriptoribus monumenta eorum, qui in variis locis factorum mutationem historiam conscripsere; & dum reliqui Authores, quorum scripta conseruata sunt, singulis tantum non annis inter portenta referant terraemotus, e terris erumpentes ignes, fluminum, & marium exundationes; facile patet quatuor mille annis multas, & varias mutationes contigisse.[77]

Furthermore, Steno added that he would introduce some obvious truths to explain all of the changes that had happened in Tuscany in a forthcoming dissertation which, unfortunately, was never published.[78]

The consideration of the Biblical confirmation, or lack thereof, of his schedule of geological events, was important to Steno, but he did not see any conflict in this area with his ideas about the age of the earth. Time had been and was to be for many scholars who applied their ideas on fossils to earth history a troublesome matter, primarily because they felt a need to make intelligible how so many fossils could have been produced in such a brief

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[77] Ibid., p. 75. It is not to be wondered that historians made no relation concerning the time of particular changes. This was because the history of the early days after the deluge is confused and dubious among secular authors; as time went on, furthermore, they tended to celebrate the acts of illustrious men and not the miracles of Nature. In addition, we do not have the books, which the ancients mention, of those writers who discussed the history of the mutations that occurred in various places. Still, among the remaining works of some authors, are reported singular happenings almost every year: earthquakes, fires erupting from the ground, and river and sea floods. It is easily patent that in four thousand years many and varied changes have happened.

[78] Ibid., pp. 75-76.

period as the six thousand years allotted to them by the Bible. Steno, on the contrary, was concerned not with how brief the earth's existence was, but indeed he sought to explain how the fossil remains could have been preserved as long as the four thousand years since the Deluge. As he wrote:

> Sunt, quibus diuturnitas temporis reliquorum argumentorum vim euertere videtur; cum núllius seculi memoria constet, inundationes eo adscendisse, vbi multa marina corpora hodie reperiuntur, si diluuium vuiuersale exceperis, vnde ad nostra vsque tempora quatuor mille anni praeter propter numerantur; nec rationi consonum videtur, tot annorum iniuriȷs restitisse animalis corporis partem; cúm videamus saepe paucorum annorum spatio eadem corpora in totum destrui. Sed huic dubio facile respondetur, cum a soli varietate id totum dependeat; strata enim ex certa argillae specie vidi, quae omnia sibi inclusa corpora tenuitate succi resolverunt; alia arenacea strata plurima obseruaui, quae omnia sibi commissa integra conseruarunt. Quo experimento liceret in cognitionem venire illius succi, qui solida corpora resoluit; quod vero certum sit, multorum conchyliorum, quae hodie reperimus, productionem ad tempora cum vniuersali diluuio coincidentia referendam esse, sufficiet sequens argumentum.[79]

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[79]Ibid., pp. 62-63. There are those who see the great length of time as destructive to the power of the remaining arguments, as no memory of any time affirms that inundations rose to the location where many marine bodies are currently found, if the universal deluge is excepted, which was about four thousand years before our age; nor does it appear rational that part of an animal's body could survive the injuries of all of those years, as we see that the same bodies are often wholly destroyed within the space of a few years. But this doubt is easily answered, as all that comes to pass relies upon the variety of the soil; for I have seen strata of a certain type of clay which by the tenuousness of their fluid resolved all of the bodies which were enclosed within them. I have observed several other sandy strata which preserved entirely all that was committed to them. By this test it could be possible to come to a cognizance of that fluid which resolves solid

The argument in question was concerned with the city of Volterra. Older than Rome, Volterra had several walls which contained all sorts of shellfish and a forum that was full of striated shells.[80] It was obvious to Steno that the shells were older than the city, but he noted that some objected that both the city and the shells were of similar age, because either the petrification of the shells, or else their envelopment by the walls, protected them from destruction. Steno countered this objection with the observation that Volterra rested upon a hill that the sea had built layer by layer and parallel to the horizon. Many of the strata on this hill had no stone, and yet these same strata often had numerous real mollusks within them which were wholly unchanged.[81] These shells were at least three thousand years old, as Rome was over two thousand four hundred years old, Volterra was much older, and that hill still older. Moreover, the deposition of all of these strata of the Volterran hill also required a long time, and it was not difficult for Steno to imagine that the addition of all of these separate periods could stretch the chronology of this area back to the times of the universal deluge.[82]

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bodies. It is, however, certain that the many mollusks which we encounter today must be referred to those times which coincide with the universal deluge, and this is sufficiently shown by the following argument.

[80] Ibid., p. 63. [81] Ibid., pp. 63-64.

[82] Ibid., p. 64.

Another example of the antiquity of fossils presented by Steno was some giant bones found in the fields about Arezzo. These bones, he was convinced, were elephant and pack-animal remains that dated from the time of the invasion of Hannibal, because: the skulls, the femurs, and the scapulae of the pack-animal did not belong to animals native to the Tuscan climate; Arezzo lay in the route of Hannibal's forces; Hannibal obviously had with him many large pack-animals and elephants; a large number of the pack-animals certainly perished in this swampy region due to floods; and, finally, the location of the bones was a place that was formed by rains which washed down various stone-filled strata and which heaped these fragments together, so that all of the facts were available to anyone who wished to compare either the bones or the place with the earth history provided by Steno.[83] Steno so further remedied a lack of historical documentation for his hypotheses.

Fossils were at the center of all of Steno's arguments. Convinced that these remains were organic in nature, he did, as did many of his contemporaries, try to solve the vexing problem of their location. Steno, though, turned this quest into a picture of an earth history. Beginning with strata deposition, he attempted to describe

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[83] Ibid., pp. 64-65.

all of the uniform operations of natural processes that had changed the earth from how it had appeared at the Creation to how it appeared in his day.

In so doing, Steno had played much more the role of the traditionalist than that of the innovator that he had hinted he was.[84] One of a number of a long line of Italian natural philosophers who were concerned with fossils, Steno did use fossils to study the history of strata. At his core, however, Steno was concerned with the agreement of the Bible and nature.[85] The six thousand year age of the earth, the universal deluge, and the rest of the historical records of Scripture were to him a true revelation of what had passed.[86] It was his obligation, as that of others before and after him, to see that his hypotheses agreed with these sacred teachings, even if it sometimes seemed that he and others acted as if affairs were to be reversed, and Scripture was to concur with his theories. It was important to remember, though, that this agreement was probably not a conscious process; for example, it was more than interesting that the earth history of both Steno and the Bible coincided in so many particulars, such as the initial water-covered age. The intimate connection of religious and secular history was thus the

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[84] Ibid., p. 69. [85] Ibid.

[86] Ibid., pp. 69-74.

paramount, if not the deliberate, aspect of Steno's work; even more, it was the justification of its existence. When seen in this perspective, the Prodromus became important as one of the theologically-orineted books that considered fossils and cosmogony that was published in this era.

Theological revelation was not so expressly significant a part of the works of other contemporaries of Steno, but even within some of these books it constituted an important role, if only for purposes of explanation. One such work was La vana speculazione of Agostino Scilla (1639-1700).[87] Scilla, a Sicilian painter, drew pictures of the rarities of nature which he had been presented with or which he had collected in person.[88] The multitude of shells from the nearby hills and from Malta were of special

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[87] Agostino Scilla, La vana specvlazione disingannata dal senso lettera responsive circa i corpi marini, che petrificati si trouvano in varij luoglu terrestri. Di Agostino Scilla pittore accademica della fvcina, detto lo scolorito. Dedicata all' illvstrissimo signore, il signor D. Carlo Gregori marchese di piggi gregorio, cavaliero della stella (Napoli: appresso Andrea Colicchia, 1670), microfilm copy (positive) of book in Vatican Library, List No. 6, Item 63 . For a contemporary review of this book see [Francis Willoughby], "La vana speculatione disingannata dal senso. Lettera risponsiva circa i corpi marini, che petrificata si trovano in varij luoghi terrestri. Di Agostino Scilla pittore accademico della fuccina, in Napoli, 1670. With short Notes, by a Fellow of the Royal Society," Philosophical Transactions, XIX, No. 219 (For the Months of January and February, 1696), 181-95.

[88] Scilla, p. +2 .

interest to him. He determined to explain their manner of origin and the reason for their inland location. In this task, Scilla rejected the opinions of those who asserted that the shells had been formed in the earth by a plastic power or by a vegetative virtue. He believed instead that the shells were actually the remains of real shells, and that they had been scattered upon the earth at some time by a great inundation.[89]

Scilla began his arguments with the supposition that Malta, which place he thought held the largest number of these so-called petrifactions, became an island shortly after the Creation. Malta, Scilla elaborated, was at that time a mass of liquid mud which was full of shells, teeth, and other remains.[90] He conjectured that these remains had been dumped upon the island by a gigantic flood, either of Mediterranean or of oceanic origin, which had agitated the waters and which had borne up many shells from the floor of the ocean to be deposited.[91] The whole mixture of mud and shells began to settle downward as the mud dried. The objects went into a position relative to their gravity, or weight, until the island became the collection of shells, teeth, earth, and stones that it was in Scilla's day.[92]

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[89] _Ibid._, pp. 1-3, 14.

[90] _Ibid._, p. 45.

[91] _Ibid._, p. 47.

[92] _Ibid._, p. 45.

Some, however, according to Scilla, objected to an organic origin of these shells. These opponents noted that formed stones were found, such as the bucardites and a certain type of turbens, which were composed entirely of a stony substance and which therefore were never shells.[93] Scilla replied that these formed stones were made of mud. Animals inside of the shells died and rotted, and mud took their places. The mud assumed the shape of the shells that enclosed it, and then it dried and hardened. Later the shell itself crumbled away and left only the dried mud.[94]

Scilla's opponents also objected that many shells were found on Malta that were not native to the seas about that island. Scilla dismissed this exception. He remarked that every wind from the southeast or east threw many shells upon the shore, none of which were taken by any fisherman in those waters.[95]

After the presentation of a theory and the consideration of objections to it, one pattern of those who believed that fossils were of an organic origin was to offer evidence for and to place great emphasis upon what they thought was an apparent visual corroboration of their views. Scilla did not deviate from this approach. He

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[93] *Ibid.*, p. 54.

[94] *Ibid.*, pp. 54-55.

[95] *Ibid.*, p. 55.

spoke of the lapides bufonitae and other stony objects that he believed were the grinders and molars of formerly alive fish, respectively. He compared the teeth in the jaw-bones of living fish with what he considered to be fossil jaw teeth.[96] He examined the glossopetrae on Malta and held that they so closely resembled the teeth of real sharks that they were of necessity naught else but such teeth. Finally, he pleaded for observers to consider as conclusive proof the growth marks that he had seen on the testaceous animals that he had removed from the rocks and mountains.[97]

The composition of the shells as well as their form was an important proof of origin to Scilla. Some argued, for example, that shells seemed to be found in various stages of growth: some were tender, and some were hard. Scilla explained that this was because some shells were opened and some were closed when they were enveloped by mud. In the closed ones, the mud was not able to cause the animal within to decay, while in the open ones it was. The former were therefore softer and lead many to doubt their true origin, even though in many of these shells the clearly visible animal parts seemingly would make their source manifest.[98]

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[96] Ibid., pp. 56-58. [97] Ibid., pp. 62-63.

[98] Ibid., pp. 64-67.

Location was another evidence of origin. Important in this category to Scilla were shell beds, soil, and the positions of individual _glossopetrae_. Many believed that shells were not animal remains because in general the shells of one sort were found concentrated in beds in one area and not in any other region. Scilla countered that this fact was in reality further confirmation of the organic origin of these shells. He believed that the Deluge had agitated the waters and had caused the shells to move violently and irregularly. With the subsidence of the waters the shells had settled according to their figure. Consequently the same kind of shells were thrown together into great heaps, and these collections later moved into locations which were determined by the rolling action of the falling waters.[99]

Scilla believed that soil composition, his second element of location, was in the places that he had investigated an overwhelming proof of his hypotheses. On Malta, for example, the soil was marl. Marl possessed a firm consistency. It therefore easily supported the heavy _glossopetrae_. These otherwise would not now be exposed to view if they had settled in the subsiding waters upon a soil of a finer consistency, such as loose sand.[100] Moreover, continued Scilla, further connecting

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[99]_Ibid._, pp. 73-74, 84. [100]_Ibid._, p. 87.

his observations about the marl to his belief in the post-diluvial settling of fossils into layers according to their weight, Maltese marl was very low in comparison to the soil on the mountains of Sicily. Scilla reasoned that the heavy Malta-like _glossopetrae_ must not be found on these Sicilian heights if his theory were valid; not surprisingly, his investigations there yielded only five. Even these five he considered as evidence for, not against, his theory, for they were filled with a light and subtle material and had little osseous matter in them.[101] Scilla also cited other examples of remains to confirm his idea. He was certain that hitherto undiscovered _glossopetrae_ were at their natural level at the bases of the mountains of Sicily.[102] He noted that the _echini_ and the _echinitae_ on Malta itself were generally seen on the beaches in easy view, and he declared that this was because both kinds of shells were lighter than the _glossopetrae_. Consequently they were more easily buoyed up by the waters than were the _glossopetrae_, and they later sank less deeply in the earth.[103]

The position of the individual _glossopetrae_, the third and final element of location, merged in Scilla's arguments with a discussion of the physical characteristics

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[101] _Ibid_. [102] _Ibid_.

[103] _Ibid_., p. 98.

of the glossopetrae. Scilla found glossopetrae in every sort of arrangement in their beds: big ones here, medium ones there, and small ones in yet another place. Some lay with roots facing upwards; others rested with roots facing downwards. Each was inclined differently. All of this diversity proved to Scilla that they were of organic origin. If they had grown in the earth as plants did, which some argued, their roots would all have faced downwards, because as plants they must have obeyed the seminal principles common to their kind.[104] Furthermore, shells of many types and in many positions were often found among the glossopetrae, and these, too, seemed not for the same reasons to be plants.[105]

It was objected, though, that although glossopetrae could easily be removed from their beds by either their sides or by their points, they stuck firmly at their bases, and when removed, they came forth with a root longer than the glossopetrae itself. They were thus plant-like and therefore were plants. Observed phenomena could be, nevertheless, evidence for opposing theories, as Scilla continued to display a facility to turn aside contradictory evidence. He retorted that this was an obvious proof of his ideas. The roots were to him not meant by nature to

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[104] Ibid., pp. 103-104. [105] Ibid., p. 104.

have conveyed nutritive juices from the soil into the *glossopetrae*. The roots were instead merely the same as the roots of any teeth, and nature intended them to hold the teeth in place in the jaws of sharks.[106] The sides and the points of the *glossopetrae* accordingly were as hard and as smooth as other teeth and so came easily from the mud.[107] The roots of the *glossopetrae*, however, had been spongy and porous and soon filled with liquid mud. This mud later hardened, and it made the roots difficult to remove.[108] Observation confirmed all of these conclusions, Scilla wrote. A comparison of *glossopetrae* and of sharks' teeth showed that even if there were minor differences among them--some were hard, others were soft; some were incrusted, others were not--yet they had many similarities, and all of them had a spongy root that was ready to fit into a cavity in a shark's jaw.[109]

Other objections were also countered by Scilla with observations. In a particular one, an opponent asked of him why black and grey conchae were found in chalk and clay while white ones were observed in rocks. Scilla replied that those in chalk and clay were only formed stones, but those in the rocks were real shells. He presented as evidence for this assertion a turbinite that had

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[106] *Ibid.*

[107] *Ibid.*

[108] *Ibid.*

[109] *Ibid.*

been sent to him by his adversary. Covered by a rocky matter, this mold had obviously been cast within a living shell, as the inner twirls were preserved intact, and as the whole mold itself turned inwards.[110] Scilla considered this single example as sufficient justification to conclude that all formed stones that resembled testaceous animals of the turbinated and bivalve kind had been cast inside of shells and always had possessed the same form.[111]

Scilla's hypotheses, drawn from his observations of the Maltese _glossopetrae_, were the core of his arguments for the organic origin of fossils. Accordingly he devoted much attention to the manifest establishment of these remains as those of the former teeth of sharks. He attacked those who described the _glossopetrae_ as productions of forces at work within the earth as, for example, those who argued that _glossopetrae_ were crystallizations of salt.[112] If this were true, Scilla declared, the _glossopetrae_ would be made up of salt within as well as of salt without, for all minerals were composed throughout of similar particles. A topaz was a topaz throughout, and granite was entirely granite.[113] _Glossopetrae_ were not minerals. They were made up of different and of various corpuscles that had been put together by nature to

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[110] _Ibid._, p. 105.

[111] _Ibid._

[112] _Ibid._, p. 109.

[113] _Ibid._, pp. 109-110.

serve a definite purpose, which was in this instance for them to be the teeth of sharks.[114]

Those who thought of _glossopetrae_ as aberrations of nature, or _lusus naturae_, also found no favor with Scilla. Nature, he admitted, often produced monstrous things. Animals without legs and trees without branches were examples of this. Despite this, nature constantly attempted to conceal its mistakes with a skin, a bark, a rind, or another device, so that no defect appeared jagged or torn to the naked eye.[115] As nature always pursued this goal, it was evident to Scilla that _glossopetrae_ were not _lusus naturae_. They were found broken and bruised. Nature had obviously made no efforts to hide their marks, which it would have if they were irregular productions of nature.[116]

Scilla's primary arguments for the organic origin of _glossopetrae_ were, as were his arguments for the origin of other fossils, based principally upon observation. He knew that _glossopetrae_ were found in beds of gravel and clay together with teeth, bones, shells, and other organic remains. He noted that _glossopetrae_ left behind them impressions in the mud that appeared to be similar to teeth in the smallest detail, even to the limbs and

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[114] _Ibid._, p. 110.

[115] _Ibid._, p. 111.

[116] _Ibid._

the cracks in the teeth.[117] Scilla also thought that the *glossopetrae* and the teeth of living sharks were so identical in appearance that he concluded from this that the processes at work in the two were similar. For example, he wrote that sharks' teeth have porous and spongy parts and that every tooth in them fitted in a special manner in their jaws. Teeth were therefore readily identifiable in regard to their positions in the mouth of the shark. Examinations then revealed whether a particular tooth belonged close to the throat or on either side of the jaws.[118] As all of these peculiarities of the sharks' teeth were seen by Scilla in *glossopetrae*, he felt as though he had established a connection between what had been hitherto considered as two different things by many.[119]

To attempt to strengthen this relationship and, indeed, to show the two remains as one to his opponents and also to confirm the organic origin of all fossils, Scilla presented both a series of written descriptions and twenty-eight tables, some with several figures. Explanations accompanied all of the figures. The former included scallop shells, echini spatagus, and the jaw bone of a dog fish that had three teeth.[120] Among the latter were the head of a cow fish with teeth in both of its jaws, a jaw

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[117] *Ibid.* [118] *Ibid.*

[119] *Ibid.* [120] *Ibid.*, pp. 114-16, 118.

of a dentex fish with grinders, a mass of petrified sea urchins, and of course sharks' teeth that had turned into stone, or glossopetrae.[121] Scilla apparently believed that this evidence was the ultimate proof of his hypotheses. He probably did not realize that any other person who saw his plates and who read his descriptions could have any interpretation save his own.

Having set aside to his own satisfaction all doubts about the organic origin of fossils, Scilla turned to the problem of their location. This he assumed was the result of a great flood, the Noachian Deluge.[122] The waters of this flood were violent. They set into motion many animate and inanimate things.[123] The waters then began to recede, and as they did so, they began to deposit the things which they had agitated. These objects settled downward according to their specific gravities, or weights, and to their figures. Consequently similar objects were thrown together, and they were later rolled about into heaps by the churning action of the falling waters.[124] Scilla hinted that all of these depositions of the waters were laid down in an order which onrushing tides regulated. The tides probably were responsible for five layers, or

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[121] Ibid., p. 169.

[122] Ibid., pp. 30-31, 47, 73-74, 124-26.

[123] Ibid., pp. 47, 84. [124] Ibid., pp. 45, 47, 84.

strata. The initial three layers served as a foundation for the other two. Gravel, coarse sand, and fine sand composed the two upper strata.[125] Scilla did not say, as Steno had, that it was possible to differentiate between the ages of the layers by their fossil contents.

Nor did he attempt any other method of establishing a chronology for the earth. He seemed content with what he, and with what several other authors of this time who wrote about fossils, considered to be the traditional Biblical story of man and of his habitat. Scilla thus operated within a pre-established framework. The Noachian Deluge was for him more than a convenient device to explain the location of fossils; it was an historical fact.[126] Scilla did not speculate outside of these fixed boundaries; indeed he could not, unless he were willing to admit the idea of change, whether of organic creatures or of the earth itself. Probably, though, a concept of the terrestrial instability of the earth, if not of its beings, never occurred to him.

This idea did occur, however, to other writers in his time. These authors moved away from a stable world and turned to a study of the earth in order to produce an earth history based upon the dictates of reason. Importantly, too, they founded their history upon Scripture, because the

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[125] Ibid., pp. 126-27. [126] Ibid., pp. 30-31.

products of reason and revelation were not yet separated in most of their minds; indeed, to them the products were necessarily the same. Scripture could then, and not surprisingly did, provide a primary source for the works of these men, even if some of their contemporaries suspected that they often perverted Scripture to accord with their own theories.

Many of those who believed in change relied, as did those who thought that fossils were of organic origin, in what they considered to be a seeming visual corroboration of their views. They began to look about them and found the earth not always changing, but ever the same, as had Aristotle, and as had others who had believed that forces were at work in the earth to maintain a balanced system. Nor did they discover an unchanging world. Instead, they imagined, as Hooke had, that volcanoes, earthquakes, floods, and other less violent phenomena had greatly altered an earth that most of them thought of as perfect at the time of the Creation. Their task, as they saw it, was to describe this fall from perfection with revelation and reason. In so doing, even if they made no commitment to the organic origin of fossils, they probably helped to guide the cosmogonal speculations of those who did.

One prominent example of such a writer was Thomas

Burnet (1635?-1715).[127] Burnet decided to harmonize revelation and nature in order to make a history of the earth based upon reason, observation, and most importantly, upon Holy Scripture. With this strong Biblical orientation, Burnet in his books attempted to describe the earth both in the past and in the coming millenium, and he therefore presented it in two parts. The first part was divided into two books. The first book concerned the Creation, the Deluge, and the dissolution of the earth. The second book was about the primeval earth and Paradise. The second

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[127]This edition of Burnet's work was bound together with several smaller works by him, listed here, which defended his ideas against critics. See Thomas 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; The Second Book Concerning the Primaeval Earth and Concerning Paradise_ (2d ed., 2 vols.; London: Printed by R. Norton for Walter Kettilby, 1691); _______, _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 Last Two Books, Concerning the Burning of the World, and Concerning the New Heavens and New Earth. The Fourth Book, Concerning the New Heavens and New Earth, and Concerning the Consummation of All Things_ (2 vols.; London: Printed by R. Norton for Walter Kettilby, 1690); _______, _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, 1690); _______, _An Answer to the Late Exceptions Made by Mr Erasmus Warren Against the Theory of the Earth_ (London: Printed by R. Norton for Walter Kettilby, 1690); and _______, _A Short Consideration of Mr Erasmus Warren's Defence of His Exceptions Against the Theory of the Earth. In a Letter to a Friend_ (London: Printed by R. Norton for Walter Kettilby, 1691).

part also contained two books, which were about the prophecies in the Bible of the final conflagration of the earth and of the new heavens and the new earth. As earth history was the history of man's home, and as the changes in the earth were the result of the action of a just God towards the humans that He had created, there was a direct coincidence between terrestrial and human history. Burnet therefore used the Bible as a reference for what had actually happened in the past and for what was to occur in the future, and he employed his reason to look at nature to determine how all of these revealed events had and were to come to pass.

Burnet also employed Scripture and reason together. One instance of this was his argument against the eternal world of Aristotle. Burnet began by noting that the Bible said that the world had both a beginning and an end. Aristotle was therefore wrong.[128] Reason also told us, he continued, that parts came before the whole, and that consequently the world was not made at once. Aristotle was wrong again.[129] Finally, observation showed that the world, if left by itself, could not endure forever. Winds, rains, storms, subterranean fires, and other violent forces destroyed without restoring. An eternal world would have

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[128] Burnet, The Two First Books, I, 34-35.

[129] Ibid., 35-37.

been submerged.[130] This also proved that the world was created--and not long since, as it was not overrun with people.[131]

Having brought the world from chaos, Burnet, employing Biblical, Greek, Egyptian, and other ancient sources,[132] established an earth that was a smooth, uniform sphere with neither sea, nor mountains, nor any other irregularity.[133] This pristine earth was a paradise. The soil was fertile, the animals and men long-lived, the climate a perpetual spring,[134] and the air tranquil.[135] Waters flowed down evenly in a mist upon this dream world and went to the center of the earth.[136] As this, however, was a world where the most important factor was change, all of this bliss collapsed with the eruption of waters from a great subterranean abyss.[137] This happened when the crust of the earth dried and cracked with age. Waters poured out of the cracks, unleashing a great Deluge that destroyed the first world.[138] This Deluge was, of course, the Deluge of Noah. So Burnet, with a few simple laws of nature, brought the first world to a close and prepared

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[130] _Ibid._, 37-38. [131] _Ibid._, 39-44.

[132] _Ibid._, 44-45, 51, 54-58, 61.

[133] _Ibid._, 66-72. [134] _Ibid._, II, 176.

[135] _Ibid._, I, 86. [136] _Ibid._, II, 226-29.

[137] _Ibid._, I, 80-81. [138] _Ibid._, 77.

for the formation of a new one from the ruins of the old,[139] for the world that was left was steadily reduced by the operations of natural forces.[140] This world itself would finally be incinerated by a great fire, and a new heaven and a new earth would rise from the ashes. Then the world would end.[141]

Burnet, despite his reliance upon Scripture, provided, as had Descartes whom he admired,[142] for a world that was relatively free from the direct intervention of God. He drew only a broad historical outline from the Bible and supplied the details from his imagination. The result was a slow progression of geological events that natural processes, or second causes, governed.[143] The procession of these processes enabled Burnet to obtain much the same outlook on earth history as Steno had. An example of this agreement was in the determination of the past form of the earth:

> I do not think it necessary to carry the story and original of the Earth, higher than Chaos, as Zoroaster and Orpheus seem to have done; but taking That for our Foundation, which Antiquity Sacred and Profane doth suppose, and Natural Reason approve and confirm, we have form'd the Earth from it. But when we say the Earth rise from a Fluid Mass, it is not to be so crudely understood, as if a block of Marble, suppose, was fluid immediately before it became Marble; no, Things had a gradual progression from

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139 *Ibid.*, 79.

140 *Ibid.*, 47-49.

141 *Ibid.*, II, 321.

142 *Ibid.*, I, 114.

143 *Ibid.*, II, 314-20.

> one form to another, and came at length to those more permanent forms they are now setled in: Stone was one [sic] Earth, and Earth was once Mud, and Mud was once fluid. And so other things may have another Kind of progression from fluidity; but all was once fluid, at least all the exteriour Regions of this Earth. And even those Stones and Rocks of Marble which we speak of seem to confess they were once soft or liquid, by those mixtures we find in them of Heterogenous Bodies, and those spots and Veins disperst thorough their substance; for these things could not happen to them after they were hard and impenetrable, in the form of Stone or Marble. And if we can soften Rocks and Stones, and run them down into their first Liquors, as these observations seem to do, we may easily believe that other Bodies also compose the Earth, were once in a fluid Mass, which is that which we call a Chaos.[144]

The difference in cosmogonal procedure between Burnet and many of those who studied fossils was that Burnet relied little on observation and much upon the Bible, while Steno and others depended much more upon the interpretation of natural phenomena to formulate an earth history.

Many were not willing to accept Burnet's ideas about what the Bible meant to say. These people thought Burnet entirely too liberal in this matter. Erasmus Warren (n.d.),[145] for example, made a refutation of Burnet's

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[144] Ibid., 324-25.

[145] Erasmus Warren, Geologia. Or, a Discourse Concerning the Earth Before the Deluge. 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 the Earth Was Not the Cause of the Universal Flood. Also a New Explication of That Flood Is Attempted by Erasmus Warren, Rector of Worlington, in Suffolk. [illegible] Ecclesiast. iii.11. Et mundum tradidit disputationi corum (London: Printed for R. Chiswell, 1690).

views the aim of his Geologia.[146] The Sacred Theory, Warren declared, was not only false; it was irreligious.[147] It so often contradicted Scripture in favor of Burnet's own theorems, that the value of the book as a whole was doubtful, for to imply that Scripture was wrong in some instances, was to imply that it was wrong in many.[148] Having thus forewarned the reader of Burnet's wrong intentions, Warren proceeded to attack The Sacred Theory in detail. For instance, he insisted upon the literal six days for the Creation,[149] and he argued that Burnet's description of the formation of the earth from chaos would have required a much longer time.[150]

Although many others, such as John Beaumont,[151] also insisted upon a stricter interpretation of Scripture, Burnet's connection of the events in Genesis with his ideas about natural processes was repeated by several writers who considered fossils. According to the authors of these works, fossils were organic remnants of a former world that

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[146] Ibid., A_2 recto.

[147] Ibid., A_2 verso, A_3 recto.

[148] Ibid., A_3 verso. [149] Ibid., pp. 50-51.

[150] Ibid., pp. 48-50.

[151] John Beaumont, Considerations on a Book, Entitled, The Theory of the Earth. Published Some Years Since by the Learned Dr. Burnet. Dedit omnibus Deus, pro virili portione sapientiam, ut & inaudita investigare possent, & audite perpendere. Lactan . de orig. error. c. 8. (London: Printed for the Author, 1693).

a universal Deluge, the Deluge of Noah, had brought to a close. Fossils were thus evidence of an Act of God of which the Word of God spoke.

All of their reasoning was in spite of works such as Beaumont's. Beaumont wondered, for example, that if the Deluge had been universal, how had Noah gotten all of the great varieties of animals onto the Ark.[152] Beaumont also questioned the reliance upon debatable causal factors and upon ancient sources to explain such events as the Deluge:

> Now if it shall be said, that the Causes they have assign'd, are not compatible for such Changes; possibly it may be, because they sought for Causes which were not in Nature to be found: For those Antients, either supposing the Deluge of the antient _Ogyges_, to have been general, or having heard that some other Deluge had been affirmed so to have been, and finding by marine Bodies dug in Mountains, that the Waters of the Sea had been there, they attempted to assign Causes for an universal Change at one effort, whereas those Causes, upon examination, were found, either to have been assign'd _gratis_, without any solid ground, or to answer only partial Change.[153]

More literal Biblical renditions of history, such as Beaumont's, however, were challenged by the books of men such as John Woodward (1665-1728)[154] and William Whiston

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[152] _Ibid._, p. 85.　　[153] _Ibid._, p. 7.

[154] 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. By John Woodward, M.D. Professor of Physick in Gresham-College, and Fellow of the Royal Society_ (London: Printed for Ric. Wilkin, 1695). This book was reviewed. See Anonymous, "V. An Account of

(1640-1695),[155] who wrote elaborate accounts which attempted to consider Mosaic history with the use of reason.

Woodward believed that fossils were organic remains of once-living creatures. His arguments for this opinion were based upon visual evidence. Some fossil shells, for example, he thought to resemble so much living shells, even to lines and other small details, that none could deny their organic origin.[156] Other shell-like remains were, he noted, less obvious in origin. Some of these were completely intermixed with mineral substances.[157] Others were merely shell molds whose places foreign substances had since filled or whose shells these substances had covered entirely.[158] Many were shells which minerals

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Books. I. An Essay Soward 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. By John Woodward. M.D. Professor of Physick of Gresham College, and Fellow of the Royal Society. Printed for Ric. Wilkins at the King's Head in St. Paul's Churchyard. 1695. Octavo," Philosophical Transactions, XIX, No. 217 (For the Month of October, 1695), 115-23.

[155]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).

[156]Woodward, pp. 22-24.

[157]*Ibid.*, p. 17.

[158]*Ibid.*, pp. 17-18.

had so completely permeated that they resembled no living shell fish.[159] A few were shells which were quite unaltered, but which had no counterparts among living shell fish.[160] Moreover, all of these remains were found scattered about over the earth from mines and quarries to the tops of high mountains.[161]

Woodward first attempted to solve the mystery of the location of the fossils. He reasoned

> . . . that the whole Terrestrial Globe was taken all to pieces and dissolved at the Deluge, the Particles of Stone, Marble, and all other solid Fossils disserved, taken up into the Water, and there sustained together with the Sea-shells and other Animal and Vegetable Bodies: and that the present Earth consists, and was formed out of that promiscuous Mass of Sand, Earth, Shells, and the rest, falling down again, and subsiding from the Water.[162]

These shells and other marine bodies settled all over the globe, at all depths and within or near all types of substances.[163] Woodward provided for this deposition much as Scilla had; he declared

> That the said terrestrial Matter is disposed into Strata or Layers, placed one upon another, in like manner as any earthy Sediment, setling down from a Fluid in great quantity, will naturally be: that these Marine Bodies are now found lodged in those Strata according to the Order of their Gravity, those which are heaviest lying deepest in the Earth, and the lighter sorts (when there are any such in the same place) shallower or nearer to the Surface and both these and those amongst terrestrial Matter which

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159 Ibid., p. 18.

160 Ibid., pp. 18-19.

161 Ibid., pp. 16-17.

162 Ibid., pp. 2-3.

163 Ibid., pp. 3-4.

> is of the same specifick Gravity that they are, the heavier Shells in Stone, the lighter in Chalk, and so of the rest, . . .[164]

An examination of this fossil evidence, Woodward declared, proved his supposition.[165] Thus Woodward explained the location of the fossils by the Deluge, and not incidentally used the fossils to show the occurrence of the Deluge. He thereby placed nature and Scripture in agreement.

Woodward then turned to the resolution of what he considered as minor difficulties about the origin of fossils. One, for instance, was the similarity of the results that chemical tests gave in the comparison of shell fossils and live shell fish.[166] Another was the explanation of metallic and mineral accretions upon and inside of fossils by visual examination.[167] The principal difficulty, though, was the objection, offered by Lister and others, that some of these so-called shell fish were unlike any shell fish then alive.[168] To this Woodward answered that even these shells had all the necessary physical characteristics that proved that they were once living shell fish.[169] To show that they had living counterparts, he continued, was no difficult matter; many shell fish, as

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[164] *Ibid.*, pp. 4-5.

[165] *Ibid.*, p. 5.

[166] *Ibid.*, p. 23.

[167] *Ibid.*, pp. 21-22.

[168] *Ibid.*, pp. 24-25.

[169] *Ibid.*, p. 25.

divers and fishermen avowed, lived too deeply in the ocean to be seen or to be cast up by storms.[170] Probably, Woodward concluded, these unseen living shell fish were there; their fossil facsimiles had, of course, been deposited inland by the Deluge[171]--an explanation that also enabled Woodward to state that "there is not any one intire species of shell-fish, formerly in being, now perish'd and lost."[172]

Having attempted to establish both that fossils were of organic origin and that fossils were evidences of a universal Deluge, Woodward nevertheless was unwilling to concede that fossils had any further role as testaments of alterations in earth history. Indeed, to Woodward, the only important change had been the Noachian Deluge, which had deposited the fossils and which had, most importantly, reduced the earth to a suitably wretched place for sinful men.[173] He was thus unwilling to allow, as Burnet had, for the destructive actions of the operations of natural forces, or second causes, embodied in rains, winds, earthquakes, volcanoes, and other agents. Woodward also rejected all other ideas which held that fossils were evidences of changes that natural forces had effected.[174] One idea in particular of those that he was adamant against,

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[170] Ibid., pp. 25-27.

[171] Ibid., p. 27.

[172] Ibid., p. 28.

[173] Ibid., p. 167.

[174] Ibid., pp. 35-44.

for example, was that of those ancients who stated that fossils marked the replacement of land by sea and sea by land. Shells were not, Woodward said

> . . . left by the Seas continual flitting and shifting its Chanel: this Progression being occasioned by the Seas wearing and gaining upon one Shore, and flinging up Mud, and, together with it, these Shells, upon the other, or opposite Coasts, thereby making perpetual Additions upon them. . . .[175]

Woodward also denied the validity of other conjectures about fossil deposition, such as those which involved the elevation of islands by earthquakes[176]; the shift of seas to alternate locations because of a change in the center of gravity in a globe that had a watery center,[177] and the encroachment of the land upon the sea by the collection of eroded matter at river deltas.[178]

Woodward thus refused to admit that fossils were indications of violent changes wrought by various agents of nature, even though he himself had argued that fossils were proofs of a violent universal Deluge. Instead Woodward claimed that all of these forces worked to establish stability. Rains returned land washed to the seas[179]; the distribution and the circulation of the oceans provided such an equilibrium between the land and the seas

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[175] _Ibid._, p. 44.

[176] _Ibid._, p. 42.

[177] _Ibid._, pp. 42-43.

[178] _Ibid._, p. 43.

[179] _Ibid._, p. 48.

that no body of water covered or uncovered lands.[180] Hence the earth of the Deluge was the same as the earth of his day, and the earth of his day would be as it was until the end of the world.[181] The Creator Himself ruled this so with His steady purposes and laws by which He governed man, His other creatures, and their domain. So it was that

> the Earth, Sea, and all natural things will continue in the state wherein they now are, without the least Senescence or Decay, without jarring, disorder, or inversion of variation of the ordinary Periods, Revolutions, and Successions of things. . . .[182]

Woodward concluded his work with the suggestion that shells, bones, and other fossil remains might be employed for a study of the conditions prevalent upon the earth before the Deluge.[183] The great number of marine shells, for example, showed that seas were larger and more salty in past times.[184] The large amount of freshwater shells indicated that the earth was once more fertile.[185] The many plant fossils revealed that the young earth had a temperate climate.[186] All of these differences, however, he stressed as pre-diluvian; he allowed no changes after that great catastrophe.

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[180] _Ibid._, p. 49.

[181] _Ibid._, p. 47.

[182] _Ibid._, p. 61.

[183] _Ibid._, p. 243.

[184] _Ibid._, pp. 252-54.

[185] _Ibid._, pp. 257-58.

[186] _Ibid._, pp. 271-73.

Quite similar and much indebted to Woodward's book was that of Whiston. Whiston, too, was devoted to the literal truth of Scripture:

> The Proposition therefore which shall be the subject of this Dissertation, and includes the whole point before us, shall be this: The Mosaick Creation is not a Nice and Philosophical account of the Origin of All Things; but an Historical and True Representation of the formation of our single Earth out of a confused Chaos, and of the successive and visible changes thereof each day, till it became the habitation of Mankind.[187]

Whiston, however, was slightly more liberal in his Scriptural interpretations than Woodward was. As the latter author, Whiston saw the Deluge as extremely disruptive in regard to both the earth and its living things, and, as Woodward again, Whiston believed that many changes had occurred in the history of the earth at the time of that great Flood. Despite this agreement between the two men, Whiston belied his intentions to strictly interpret the account of the Creation in Genesis. He made an immediate and lengthy explanation of both what Scripture said and what it meant to say about this matter.[188] One example of his interpretation was his belief that the world had been created before the six day Creation account given in Genesis, a belief that increased the age of the earth and incidentally provided for some type of evolution of

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[187] Ibid., p. 3.

[188] Whiston, pp. 1-94.

the earth's living beings. As Whiston noted, on the latter subject, the words creating, making, and framing

> . . . signifie no more than the ordering, disposing, changing or new modelling those Creatures which existed already, into a different, and sometimes perhaps a better, and more useful state than they were in before.[190]

Further pursuing this topic, Whiston added, concerning the preservation of these created species, that he could not

> . . . imagine that God is peculiarly fond of any particular part of the Material Creation, or any more a _Respecter_ of some _inanimate Bodies_, than of _Persons_.[191]

Regular changes not only in the creatures, but also in their habitats, were stressed by Whiston as well, but he did not say whether fossils were confirmations of all such changes. He did, however, speak much about these alterations, which he apparently believed happened on no less than three occasions: at the Creation, at the Fall of man, and at the Deluge. So it was that he intimately connected secular and biblical history; if man, for example, changed after his first sin, then so too did the environment that surrounded him, for a fallen being deserved not Paradise.[192] Moreover, the fallen became worse after the Deluge, as climatic changes outside provoked changes inside of the earth's creatures.[193]

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[190] _Ibid._ [191] _Ibid._, pp. 92-93.

[192] _Ibid._, pp. 100-102. [193] _Ibid._, pp. 110-16.

Not all of Whiston's conjectures were based upon such tedious elucidations of Scripture; he presented fossils as more tangible support for the incidence of the Deluge. Whiston believed that a great portion of the upper crust of the earth dissolved when a comet swept too close to the earth and initiated the Deluge of Noah. The crust, together with an immense number of bones, shells, vegetables, and other remains of living things destroyed by the waters, mixed with a new mass of earth, whose origin Whiston did not determine, though perhaps it was from the comet, as was most of the diluvial rain.[194] Later this mixture began to settle downward into parallel strata according to the individual specific gravities of each of its components; the heaviest objects dropped first and the lighter ones came down later.[195] Eventually the strata, for a reason Whiston did not give, became dislocated and broken. The strata continued in this manner, being elevated in some regions and depressed in others, until the earth's surface had acquired all of its present irregularities. Despite this disruption of the strata, Whiston concluded that since

> . . . the Deluge there neither has been, nor will be, any great and general Changes in the state of the World, till that time when a Period is to be put to the present Course of Nature.[196]

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[194] *Ibid.*, pp. 201-02. [195] *Ibid.*, pp. 202-03.

[196] *Ibid.*, p. 208.

Next to Genesis, Whiston's most heavily cited reference was the Essay of Woodward. Whiston relied much upon this work, both for Woodward's observations about fossils and for his ideas about the dissolution of the earth at the time of the Deluge. Nevertheless, Whiston rejected that theory as a whole, noting that if it were not so fantastic, and if no other explanation were feasible, it might be true.[197] So he was moved to theorize independently.

Whiston's own conjectures were an indication of how well accepted by many the organic origin of fossils had become by this time. Not all theorists now devoted lengthy pages of observation and theory to show that fossils were the remains of plants and animals. Many instead used fossils as support for other suppositions, which by the age of Whiston included the employment of fossils as evidence for an event described in a revealed work. Fossils indeed were sufficiently important to cause a few, if limited, alterations in previously accepted ideas about the past history of the earth. For a number then, the fossil question had been resolved, but the resolution posed new questions for these natural philosophers.

Another example of this use of fossils was the Protogaea of Gottfried Wilhelm Leibniz (1646-1716).[198]

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[197] Ibid., pp. 200-202.

[198] Gottfried Wilhelm Leibniz, Svmmi polyhistoris

Leibniz did exert a considerable effort in this book to show that fossils were organic remains and not sports of nature. Depending greatly upon what he considered to be visual corroboration, he compared fossils with living marine creatures. One example of this was his discussion of Maltese glossopetrae.[199] Leibniz included for further support twelve tables with figures of glossopetrae, marine shells, and animal remains.[200] In addition, he cited other works in his defense, including ones by Scilla and Steno.[201] Leibniz ridiculed those who denied this evidence, and he especially mocked those who believed that forces in nature had reproduced figures upon stones such as representations of Moses and the Ascension of Christ.[202]

Leibniz also applied fossils as evidence for his theory of the earth. He believed that the earth was in the beginning entirely a ball of molten liquid. Since its inception, the earth had been slowly cooling, contracting,

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Godefridi Gvilielmi Leibnitii Protogaea sive de prima facie tellvris et antiqvissimae historiae vestigiis in ipsis natvrae monvmentis dissertatio ex schedis manvscriptis viri illvstris in lvcem edita a Christiano Lvdovico Scheidio (Goettingae: Svmptibus Ioh. Gvil. Schmidii, bibliopolae universit, 1749). An earlier version was available, however, in a short resume. See _______, "Protogaea autore G.G.L.," Acta Eruditorum, II, 2d ser. (Mensis Januarii 1693), 40-42.

[199] Leibniz, Svmmi, pp. 48-49.

[200] Ibid., opposite p. 86.

[201] Ibid., p. 48.

[202] Ibid., pp. 33-34.

and acquiring a new crust.[203] Water condensed as the cooling continued, and it collected to become the oceans.[204] Meanwhile the crust thickened and as it did so it trapped great particles of air and water beneath its surface. When the roofs of the caverns full of air collapsed, they created valleys. The sides of these caverns became mountains.[205] When the caverns full of water broke, floods occurred which deposited waste material as sediment.[206] Underground explosions of gases and the weight of the crust protracted this system of collapse and flood until the present surface of the earth appeared.[207]

Leibniz thus provided two natural causes for his geological operations, fire and surface waters. Matter of a fiery origin formed the base of the earth's surface; fiery rocks from the hot interior of the earth and sedimentation from surface waters which excavated hollows supplied the upper layers.[208] As evidence for these views, Leibniz offered fossils. He noted that the various layers of sediment were distinguishable by their fossil contents, and he mentioned Steno to substantiate this claim.[209]

History from Holy Scripture, especially the Deluge,

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[203] _Ibid._, p. 2.

[204] _Ibid._, pp. 5-6.

[205] _Ibid._, pp. 6-7.

[206] _Ibid._

[207] _Ibid._, pp. 7-9.

[208] _Ibid._, pp. 8-9.

[209] _Ibid._, pp. 35-36.

constituted a part of this theory. The earth, Leibniz wrote, was at one time entirely submerged. Proof of this was in Scripture, in ancient sources, and, most of all, in the objects left by the sea upon the land, such as shells, amber, and glossopetrae.[210] Leibniz discounted those diluvial theories whose causes opposed the undeniable revelations that Scripture presented.[211] He referred those in doubt of a reasonable and Scripturally correct theory to the speculations of Burnet and Steno.[212]

Leibniz concluded his book with a hint that a study of fossils might enable philosophers to understand unknown segments of past time. Vast changes in the earth, for example, must have been matched by corresponding changes in animal life, as the many varied and strange fossil forms which had no living counterparts seemed to indicate.[213] Another change visible in many places, he continued, was that of stages in sedimentation. He studied different sedimentary strata at Amsterdam and remarked that each was so different in its composition and contents that together they marked the rise and fall of the ocean.[214] Leibniz noted that such studies of nature's clues opened the past to us. As he wrote:

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[210] Ibid., p. 9.

[211] Ibid., pp. 9-12.

[212] Ibid., pp. 12-13.

[213] Ibid., pp. 41-42.

[214] Ibid., pp. 85-86.

<u>Ita rerum natura praestat nobis Historiae vicem. Historia autem nostra hanc contra gratiam naturae rependit, ne praeclara eius opera, quae nobis adhuc patent, posterius ignorentur.</u>[215]

In the half century from 1650 to 1700 interest in fossils was great. Many came in this era to regard fossils as the remains of once-living animals and plants and not as objects of inorganic origin. The resolution of this ancient problem for many did not, however, end the study of fossils. These philosophers began to use fossils as important and necessary elements in their accounts of the history of the earth, and the fossil record provided for them evidence for both traditional events, such as the Deluge of Noah, and for their own conjectures.

Perhaps this acceptance by several of the organic theory was explainable as a consequence of the renewed interest in Biblical history late in this period. It probably seemed easier for them to view fossils as organic remnants of the Deluge rather than to see fossils in a more mysterious way, such as sports of nature. It was more likely, though, that the organic theory of fossils and the Deluge accommodated each other; the Deluge explained the location of fossils and the fossils showed that the Deluge had occurred. It was not plausible, as some scholars later

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[215] <u>Ibid</u>., p. 86. "So the works of nature provide a history for us. Our history, though, repays this boon back to nature, for it preserves her illustrious works, as nearly as we are able to understand them, so that our posterity will not be ignorant of them."

suggested, that fossils were received as organic because of an overwhelming mass of visual evidence, and that therefore earth history, including terrestrial and Biblical history had to be rebuilt about them. No theory in science was ever accepted because it was proved to be true, and the organic theory of fossils was no exception to this rule. The theory became accepted by many because, as all successful theories, it was more suitable to the mental concepts of its recipients than were other counter theories. As such, it was not then triumphant because it was revolutionary, but rather because it better fit established patterns of thought.

Once accepted by many as of organic origin, fossils began to raise perplexing difficulties to natural philosophers. Among these problems that fossils posed were the extinction or the alteration of species, an increased age of the earth, and the deposition of the strata of the earth. These questions in themselves were only minor indications, however, of how important the study of fossils had become by 1700; more revealingly, a number of authors who discussed earth history at that date used fossils as major evidence for the support of their theories. Fossils thus evolved, to many natural philosophers within this period of discussion, from merely interesting objects observed about the earth to highly significant aids in comprehending the past.

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