71-12,564

DeLUCA, Frederick Peter, 1931-
THE DEVELOPMENT AND IMPLEMENTATION OF STRUCTURED INQUIRY METHODS AND MATERIALS FOR AN INTRODUCTORY GEOLOGY LABORATORY COURSE AND THEIR EFFECTIVENESS AS COMPARED WITH THE TRADITIONAL COURSE.

The University of Oklahoma, Ph.D., 1970
Education, scientific

University Microfilms, A XEROX Company, Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE DEVELOPMENT AND IMPLEMENTATION OF STRUCTURED INQUIRY METHODS AND MATERIALS FOR AN INTRODUCTORY GEOLOGY LABORATORY COURSE AND THEIR EFFECTIVENESS AS COMPARED WITH THE TRADITIONAL COURSE

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

FREDERICK PETER DeLUCA

Norman, Oklahoma

1970

THE DEVELOPMENT AND IMPLEMENTATION OF STRUCTURED INQUIRY

METHODS AND MATERIALS FOR AN INTRODUCTORY GEOLOGY

LABORATORY COURSE AND THEIR EFFECTIVENESS AS

COMPARED WITH THE TRADITIONAL COURSE

APPROVED BY

DISSERTATION COMMITTEE

ACKNOWLEDGEMENTS

I recognize and acknowledge that the study reported herein was made possible through the combined efforts, helpful suggestions and cooperation of many individuals. I am most grateful to Dr. John W. Renner, my major professor, for opening doors, guiding the way and assisting in the final preparation of this report. I also express my gratitude to Dr. Herbert R. Hengst and Dr. Gene D. Shepherd for their constructive criticism toward the improvement of the prospectus and culmination of this report.

Special acknowledgement and appreciation are extended to Dr. Charles J. Mankin and Dr. Edward C. Stoever, Jr. for their early and continued support of the study. I am also grateful to Dr. Mankin for his assistance in finding funds for purchasing laboratory materials, coordinating computer activities, and assisting in the formulation of this report. To the many professors and graduate students in the School of Geology and Geophysics, I extend my gratitude for the discussions and the ideas that evolved.

My sincere thanks go to Mrs. Anita Starzer and her assistants for their help with the typing and tedium, and for their tolerance of the constant clutter in Room 324.

And finally, to my wife Candelas, the girl who learned much more about doing a dissertation than she really cared to know, my deepest

and warmest appreciation for her assistance, encouragement, understanding, and willingness to endure the trials and tribulations of graduate study.

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CHAPTER I

INTRODUCTION

As new knowledge is accumulated and changes in society occur, concomitant changes in curriculum must also take place, not only to facilitate the continuation of the production of new knowledge, but also to encourage its application toward the solution of problems in a changing society. Thus curriculum development and evaluation in higher education, a problem of antiquity, must be an ongoing process that rides the crest of change. The present crisis in curriculum reform in higher education,[1,2] however, appears to have precipitated primarily from an inherent reluctance to change during a time of an accelerated accumulation of knowledge and the development of a whole new battery of unsolved problems of society. This situation gives impetus to the speculation that the development and

[1] "Crisis on the Campus: A Selection of Recent and Forthcoming Books," The Saturday Evening Post, September 21, 1968, p. 66.

[2] The overall crisis in higher education involves adjustment of institutions of higher learning to a changing society. The crisis referred to in this paper centers on changes in curriculum as an integral part of that adjustment.

evaluation of curricula in higher education must receive greater attention if the gap between knowledge and unsolved problems of society is to be reduced.

Higher education is slow to change, and paradoxically, while it has been instrumental in pioneering changes in the elementary and secondary schools, specially since the advent of Sputnik, relatively little change has taken place in higher education itself. Reasons for the lack of change are numerous and complex. The important point is that, as a result of the increased interest in curriculum development and evaluation in higher education, one is encouraged that the situation will be ameliorated.

Undergraduate geological education is an example of one discipline where interest and progress have been shown on the departmental level of various institutions and on a national level through the efforts of the American Geological Institute, an organization composed of sixteen societies in geology. Concern for curriculum improvement led to the formation of a member society in May, 1938, when a small group of interested geologists in the Middle West founded the Association of Geology Teachers, now known as the National Association of Geology Teachers. Since the time of inception, the National Association of Geology Teachers has played a major role in geological education, primarily through its voice the Journal of Geological Education. The association's activities are in keeping with Article II of the national constitution which states: "The purpose of this association shall be to foster improvement in the teaching of the earth sciences and to disseminate knowledge in this field to the general public."[3]

Interest in geological education grew during the 1940's and 1950's as was reflected by the growth and distribution of the Journal of Geological Education.[4] In 1962, in response to the charges that the geology curricula were outmoded and obsolete, the American Geological Institute, supported by a two-year grant from the National Science Foundation, initiated "GEO-Study" (Geological Education Orientation Study). On May 11-12, 1962, an interdisciplinary conference, "Changing a Pattern of Undergraduate Education in a Discipline,"[5] was held in Chicago. Distinguished representatives from the fields of geology, education, physics, mathematics, chemistry, mechanical engineering, psychology, business, and administration in higher education met to discuss the problems, relationships, and possible procedures for curriculum development.

As a result of the conference, ten visiting teams, each consisting of three to five professors of geology, were formed in an effort to gather data concerning the nature of present programs, problems, and possible solutions. The Visiting-Team Reports later served as the basis for a second interdisciplinary meeting that was held in Boulder, Colorado, July 25-27, 1963, to discuss several key problems of geological education, outline possible solutions to the problems, and provide direction for

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[3]Kurt E. Lowe, "The First Milestone," Journal of Geological Education, I, no. 3 (April, 1952), p. 1.

[4]This growth in terms of changes in format and volume of content can best be seen by way of a brief survey of the Journal of Geological Education since its inception in 1938.

[5]William B. Hambleton, "The Status of Undergraduate Geological Education: A GEO-Study Report," Geotimes, VIII, no. 4, Part A (November-December, 1963), p. 3.

future GEO-Study activity. The results of the conference were reported in a special issue of Geotimes.[6]

Although GEO-Study terminated after two years, progress continues to be fostered by the Council of Education in the Geological Sciences (CEGS), a project of the American Geological Institute. One area of interest that has been emphasized by GEO-Study, and continues to receive a great deal of attention from the Council of Education in the Geological Sciences, is the college introductory geology program. High interest in the introductory geology program stems from its strategic position as a stepping stone to more advanced courses in geology, and the desire for it to serve as a relevant course for the non-major. Toward these ends, many alternatives for improvement have been suggested. For example the Council is presently engaged in the designing and testing of laboratory activities, and is encouraging departments of geology to incorporate them in their program on a trial-criticism-improvement basis.[7,8] Although the efforts of GEO-Study and CEGS have analyzed and established direction for improvement in the introductory geology program, much more

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[6] Ibid., et al., Part B, 1964.

[7] Council on Education in the Geological Sciences, "Problems in Physical Geology," special issue of the Journal of Geological Education, XV, 6, (December, 1967), 219-79.

[8] The Council encourages college professors to develop dynamic, prototype instructional modules to introduce interdisciplinary aspects of specific geological problems to the student and to offer him an opportunity to work independently at his own pace. Each module is tested at the designer's home institution prior to further testing at other institutions that are selected by the designer and the Council. After each trial, the materials are modified by the designer and the Council until the module is deemed suitable for commercial distribution. The first two modules for distribution will be ready for the 1970-71 academic year.

work remains to be done. Especially important, if the early efforts of GEO-Study and CEGS are to be exploited, is the analysis of curriculum problems found in individual departments of geology, and the design and implementation of possible solutions. Paramount to this goal is the concomitant need for evaluation of new curricula under controlled conditions--a process that is obviously lacking now.

Purpose of the Study

The purpose of the study was twofold: (1) design of an introductory geology laboratory course that will overcome the problems of the traditional course without reduction in student achievement or favorable attitude; (2) test the inquiry hypothesis; viz., when some students of introductory geology are taught by the experimental laboratory course and other students are taught by the traditional laboratory course, upon comparison of the results, the students taught by the experimental laboratory course will show a significantly greater achievement in understanding geology and in favorable attitude toward their laboratory course.

"Problems of the traditional course" referred to:

(1) How could the amount of lecture-time by the laboratory instructor be reduced or used more effectively?

(2) How could the student be encouraged to take a more active part in the laboratory course?

(3) How could the laboratory instructors be guided toward a more effective role?

(4) How could the unarticulated content matter be integrated?

(5) What methods and materials could be utilized to facilitate concept development?

(6) How could an outdoor activity be simulated indoors?

(7) How could one compensate for the low degree of correlation between the lecture section and the laboratory course?

Evaluation of the Problem

The introductory geology laboratory course at the University of Oklahoma is an integral part of the introductory geology program which enrolls about 700 students per semester. The total complement of students represents a cross section of undergraduate disciplines including geology majors. All students are required to attend three one-hour lecture and one three-hour laboratory period per week, plus one all-day field trip during the latter part of the course. The lecture sections are conducted by professors or special instructors of geology, and the laboratories are conducted by graduate assistants who serve under the guidance of a geology professor.

Evaluation of the problem commenced with the inception of the 1968 spring semester, when this investigator assumed a position as a graduate assistant and instructor in the introductory geology laboratory course. This position provided an opportunity to discuss the problem with those who were most closely associated with it, viz., faculty members, laboratory instructors, and students. Another source of information came from discussions with visiting professors, guest lecturers, and through personal communications with personnel at other institutions.[9,10,11]

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[9]William A. S. Sarjeant, Visiting Professor of Geology at The University of Oklahoma, 1967-68.

[10]O. T. Hayward, "New Approaches to Geological Education," lecture at the University of Oklahoma, May, 1968.

[11]Letter from David M. Delo, Program Coordinator, Council on Education in the Geological Sciences, Washington, D. C., April 1, 1968.

Further insight into the nature of the problem on a national level was gained through a search of the literature in the Journal of Geological Education, Journal of Research in Science Teaching, Dissertation Abstracts, and other sources as cited in this and subsequent chapters.

The evaluation process paid specific attention to three aspects that were common to most curriculum problems: (1) the goals for the course, (2) the academic background of the students, and (3) the material and methods utilized. Data concerning the first two aspects, goals and academic background, were gathered by way of questionnaires (see Appendices A and B). Members of the geology faculty responded to a questionnaire concerning the goals for the introductory geology program, and 358 of the 549 students enrolled in introductory geology during the 1968 spring semester filled out questionnaires that yielded data on academic background. The third aspect, methods and materials utilized, was evaluated through this investigator's capacity as a laboratory instructor. Data on the above aspects of the course served as a basis for the compilation and design of specific laboratory materials and activities toward the formulation of a course that was well integrated and insured a continuum between the student and goals.

Formulation of the Problem

The problem under investigation was: Can an introductory geology laboratory course be designed to overcome the problems of the traditional course and show a significant increase in achievement and favorable student attitude?

"A significant increase" was determined by measuring and comparing the performance of students taught by the traditional method (control group) and those taught by the experimental course. Measurement was carried-out by two instruments: (1) a teacher-constructed geology achievement test, (2) a teacher-constructed attitude test based on Osgood's semantic differential technique.[12] The level of significance was determined by application of the appropriate statistical test.[13]

Need for the Study

Need for the study had been expressed by the chairman of the School of Geology and Geophysics, Dr. Charles J. Mankin, through his enthusiastic encouragement and assistance with hopes that such a study would provide direction for further work in geology curricula. Several geology faculty members had also expressed their support through helpful suggestions, cooperation and an expressed desire to try a change in approach to the laboratory course.

On the national scene the need for this research was stated most succinctly by Hambleton when he said, "GEO-Study (Geological Education Orientation Study) an enterprise of the American Geological Institute, was undertaken in response to charges that geology lacks purpose and direction, that its curricula are outmoded and obsolete, that it is static and it no longer attracts gifted students."[14] In the same publication, Hambleton presented a detailed account of the status of geological education

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[12]Charles E. Osgood, George J. Suci, and Percy H. Tannenbaum, The Measurement of Meaning (Urbana: University of Illinois Press, 1957).

[13]Chapter 5 of this paper is devoted to the collection, analysis and interpretation of data.

[14]William B. Hambleton, "The Status of Undergraduate Geological Education: A GEO-Study Report," Geotimes, VIII, no. 4, Part A (November-December, 1963), p. 1.

and the need for change. In 1964, Hambleton and others reported the proceedings of an interdisciplinary meeting at Boulder, Colorado, and indicated that much time and interest were devoted to the problems of the introductory geology program.

> On the first day the conference examined the introductory course and attempted to answer questions concerning whom we are trying to serve, possibilities of satisfactory new approaches, the role of related sciences, the role of laboratory and field studies, and the character of the introductory course if many future students will have had earth science in high school.[15]

The development of earth science courses for the secondary schools and its subsequent effects is becoming more evident on the college level. Roy expressed concern for the affects that earth science courses on the secondary level would have on college programs when he stated "The growth of earth science as a full year course in junior high schools is exceeding all expectations and predictions . . . . To meet these needs requires curriculum reform as well as course revision."[16]

Ellison also expressed concern for the problem:

> Another part of the scene that affects my thinking on the subject matter of geology is what impact will the Earth Science Curriculum Project[17] (ESCP) have on college teaching within the next ten years . . . . Even now I am alarmed at the remarkable amount of uniformity among the various colleges in both their curricula and the course subject titles in geology. . . . We must try new titles, new subjects, and new array of ideas.[18]

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[15]Ibid., et al. Part B, 1964, p. 2.

[16]Chalmer J. Roy, "Let's Teach Geology as the Science of the Earth," Journal of Geological Education XIV, no. 2 (April, 1966), p. 50.

[17]Earth Science Curriculum Project, a project oriented toward the teaching of earth science in the secondary schools, Boulder, Colorado, 1963.

[18]Samuel P. Ellison, Jr., "A Philosophy of Geological Education," Journal of Geological Education, XIV, no. 1 (February, 1966), p. 4.

Stoever recently conducted a survey of secondary schools in Oklahoma in an attempt to determine the growth of earth science courses in that state. A conservative tabulation based on 196 responses indicated a rapid increase in the number of schools and students involved in earth science courses. He stated:

> Since most of the growth in Oklahoma has occurred within just the past three years, it would appear likely that the enrollment in 1970-71 will exceed by a large margin the 33 1/3 percent predicted by ESCP by that year . . . no less than 58 schools are definitely planning on adding the course by 1970, and 44 additional schools have tentative hopes to adopt the course at some time within the next few years. In other words, by the 1970-71 school year there may be as many as 102 schools in Oklahoma teaching ESCP![19]

The lack of research in geological education and more specifically in introductory geology laboratory courses as indicated by the literature cited serves to further justify the need for work in this area. As recently as March, 1968, John Snyder, Director of Education, American Geological Institute, stated, "Very little research on the teaching of geology has ever been done. In the last 15 issues [three years] of the Journal of Geological Education, only 2 articles deal specifically with teaching research."[20]

Such a study should prove beneficial to curriculum development at the University of Oklahoma, but since many of the problems are common to other institutions, it should also be of national interest. The research design with its questionnaires, measuring instruments, and

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[19]Edward C. Stoever, Jr., "Earth Science in Oklahoma," ESCP Newsletter, no. 16 (May, 1968), p. 4.

[20]John Snyder, "Education - A Special Issue," Geotimes XIII, no. 3 (March, 1968), p. 9.

procedures, could serve as a guide for future research. The development of methods and materials; organized in a specific sequence that pays attention to student academic background, goals and integration of content; should be helpful toward student participation and the establishment of guidelines for the laboratory instructors. The latter point is extremely important to institutions that utilize graduate assistants for instruction in the laboratory. One can also expect that such a study will shed some light on the advantages and disadvantages of a structured inquiry approach as opposed to the present or traditional approach.

Limitations of the Study

The study was subjected to the following limitations:

(1) Only the introductory laboratory course at The University of Oklahoma was studied.

(2) The independent variables were method and materials, and teacher. Since both method and materials were combined and treated as one variable, the detection of a separate effect for each was precluded.

(3) Only the dependent variables, achievement and attitude, were measured. Thus the relationship of the independent variables to other aspects of student behavior was purely speculative.

(4) The content of both courses, the traditional and the experimental, was the same as that of the traditional course. This was necessary in order to establish a basis for comparison between the traditional and experimental

approaches in terms of method and material, and it did not rule out the possibility that other batteries of content matter may have been superior or better suited for an introductory geology course.

(5) The degree of inquiry was limited by the class schedule, laboratory sheets, confinement to the classroom and prior conditioning of the students by past educational experience.

(6) The experiment was conducted for the duration of one semester.

CHAPTER II

BACKGROUND OF THE PROBLEM

Common reference to the inquiry approach to learning and teaching as the "Socratic Method" attests to its origin in antiquity, and therefore, should dispel the myth that it is a new concept in education. The history of education indicates that some form of learning and teaching by inquiry has waxed and waned throughout at least the past two thousand years. The new aspect, however, is that only within the last decade has it flourished to revolutionary proportions, for never before has inquiry undergone a revival of such great magnitude. Although precise data concerning the actual numbers of students and teachers involved in inquiry are lacking, indirect estimates may be made according to the growth in number of books, articles, research reports and curriculum projects relating to inquiry.[21] Regardless of the level of estimation, increased interest in inquiry during the past decade is obviously evident.

The purpose of this chapter is to clarify the nature of inquiry as it applies to the learning-teaching process, and to examine the research in education as it relates to this study. The relative paucity of information on inquiry in the literature in higher education necessitates the

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[21]David P. Butts, ed., Designs for Progress in Science Education (Washington, D.C.: National Science Teachers Association, Inc., 1969), p. x.

drawing of ideas and concepts from the literature in elementary and secondary education where information on inquiry abounds. All of the following concepts, regardless of their source, apply equally as well or more so to the level of higher education.

Learning and Teaching by Inquiry

Let it be stated from the beginning: inquiry is an extremely complex process that to date has eluded all attempts to describe it in simple and concise terms that meet with general agreement in the educational community. Inquiry is a dynamic process, shifting according to the myriad factors it encompasses. It is a nebulous process and as such it is elusive and gives rise to a diverse range of definitions as characterized by the language of the learning theorist at one extreme and the uninitiated layman at the opposite extreme. Inquiry appears to be many "things" to many people.

The problem of defining inquiry is somewhat compounded by the use of several terms that may be substituted for the word inquiry; viz., inductive, investigative, science, discovery and descriptive. Support for the use of one term rather than another term may exist in the form of subtle distinctions; however, this writer views the distinctions as purely semantic in nature and he will continue to treat them as equivalents.

Robert Glaser alluded to the inherently complex nature of inquiry (discovery) when he stated:

> Finally, the excursion that this paper has taken into the intricacies of 'discovery learning' brings to mind the admonition of Edward L. Thorndike who wrote the following: '. . . if we avoid thought by loose and empty terms, or if we stay lost in wonder at the extraordinary versatility and inventiveness of higher forms

of learning, we shall never understand man's progress
or control his education.'[22]

Contrary to its evasive tendency, inquiry has a core, framework or inner skeleton which many writers have attempted to expose and communicate. Dewey had that structure in mind when he defined inquiry as the "Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends."[23] Bridgman suggested that science (inquiry) is taking place anytime an individual is "doing one's damndest with one's mind, no holds barred."[24]

In 1960, Bruner[25] used the phrase, "learning how to learn," in reference to the work that had taken place in educational psychology at about the turn of the century. Subsequently, the phrase has been commonly employed in educational literature to define the inquiry process. Feynman suggested that science (inquiry) is a process in which one recognizes the ignorance of experts and the need for uninhibited quest for discovery and confirmation.[26]

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[22]Robert Glaser, "Variables in Discovery Learning," in Learning by Discovery: A Critical Appraisal, ed. by Lee S. Shulman and Evan R. Keislar (Chicago: Rand McNally & Company, 1966), p. 26.

[23]John Dewey, How We Think: A Restatement of the Relation of Reflective Thinking to the Education Process (Boston: D.C. Heath and Company, 1933), p. 9.

[24]P. W. Bridgman, "Prospects for Intelligence," Yale Review, 34, 1945, 450.

[25]Jerome S. Bruner, The Process of Education (New York: Vintage Books, 1960), p. 6.

[26]Richard P. Feynman, "What is Science," A paper presented at the Fourteenth Annual Convention of the National Science Teachers Association. New York, 1966.

Comparable definitions were formulated by many other writers, and they, as did those above, recognized that a phrase or a few sentences were not enough to communicate the true nature of learning and teaching by inquiry, especially to the uninitiated, so they expanded on their condensed definition by way of examples of inquiry in practice. The rediscovery of Dewey's work helped but the early 1960's was a time of experimentation, and precise examples of inquiry were lacking. Each educator was grappling for a more"refined" meaning of inquiry as it continued to undergo change with each new trial in the classroom. The question that had to be answered was; How can one define inquiry so that it bridges the gap between the ideal world and the operational world of the classroom?

As more inquiry oriented programs were implemented in the elementary, secondary schools, and relatively few in higher education, the latter half of the 1960's witnessed a higher level of communications concerning the nature of learning and teaching by inquiry. Several writers shifted the emphasis to the operational level; they realized that definitions in the theoretical realm were not adequate, and one had to explain the role of the teacher and the student in order to convey a more precise meaning of learning and teaching by inquiry. This shift to combine theory and practice was made possible through the direct involvement and cooperation between educators in higher education and in the classrooms of our elementary and secondary schools. Such pioneer efforts were spurred on by the financial support from numerous government agencies.

The result was that the latter part of the 1960's produced several books that were much more successful than earlier writings that had attempted to explain the nature of learning and teaching by inquiry.

Renner and Ragan[27] dissected the inquiry process in the elementary schools with a degree of clarity far beyond that found by earlier treatises. Romey[28] contributed to the understanding of learning and teaching by inquiry in the secondary school by way of special examples drawn from the earth sciences. Massialas and Zevin[29] emphasized the point that inquiry was also applicable to learning and teaching in disciplines other than the natural sciences; they used numerous examples from the fine arts and social sciences. Schaefer's[30] theme that the schools should be centers of inquiry was taken and expanded upon by Postman and Weingartner[31] by way of drawing on the contemporary writings outside the field of education.

The point to be recognized is that the foregoing writers found that it is necessary to devote entire books to learning and teaching by inquiry in order to clarify its meaning. Although such an undertaking is beyond the scope of this paper, the rudiments of learning and teaching by inquiry may be grasped by drawing a comparison with the traditional approach[32] to learning and teaching. In so doing, one is comparing a

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[27]John W. Renner and William B. Ragan, Teaching Science in the Elementary School (New York: Harper and Row, 1968).

[28]William D. Romey, Inquiry Techniques for Teaching Science (Englewood Cliffs, New Jersey, 1968).

[29]Bryon G. Massialas and Jack Zevin, Creative Encounters in the Classroom: Teaching and Learning Through Discovery (New York: John Wiley & Sons, Inc., 1967).

[30]Robert J. Schaefer, The School as a Center of Inquiry (New York: Harper & Row, 1967).

[31]Neil Postman and Charles Weingartner, Teaching as a Subversive Activity (New York: Delacorte Press, 1969).

[32]Although the writer refers to the traditional approach and the inquiry approach in order to facilitate discussion, he recognizes varying degrees of both approaches.

known or familiar process; viz., the traditional approach, to a new or unfamiliar process, the inquiry approach. Moreover, the possibility for understanding is enhanced by drawing the comparison on an operational level, between three factors common to both approaches.[33] These factors are:

1. The role of the teacher
2. The role of the student
3. The mode of evaluation of the student.

As a point of departure, perhaps a review of the traditional approach will be helpful. Dewey succinctly summarized the philosophy and procedures of the traditional approach as follows:

> If the underlying ideas of the former traditional approach are formulated broadly, without the qualifications required for accurate statement, they are found to be as follows: The subject-matter of education consists of bodies of information and of skills that have been worked out in the past; therefore, the chief business of the school is to transmit them to the new generation. In the past, there have also been developed standards and rules of conduct; moral training consists in forming habits of action in conformity with these rules and standards. Finally the general pattern of school organization ... its time schedules, schemes of classification, of examination and promotion, of rules of order, and I think you will grasp what is meant by 'pattern of organization.'[34]

Dewey's description of the traditional approach, if one is willing to think in terms of polarized positions of "The Learning-Teaching Spectrum" (Figure 2-1), marks one extreme on the continuum--

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[33]The writer recognizes an indebtedness to professors John W. Renner and Gene D. Shepherd for introducing him to many of the following ideas and techniques for clarifying the meaning of learning and teaching by inquiry.

[34]John Dewey, Experience and Education (New York: Collier Books, 1938), pp. 17-18.

a position that represents the dominant mode of operation in our schools today.[35]

Pure Inquiry — Pure Traditional

X ←——————————————————→ X

Figure 2-1. The learning-teaching spectrum

One must note that the use of the word "traditional" as it is used above and on subsequent pages in this report denotes an extreme position of an approach that has dominated teaching in the past and continues to do so today. It makes no reference to the many other approaches that correspond to intermediate positions on The Learning-Teaching Spectrum and have been used in the past. Its essential characteristics are a recognized body of knowledge, a teacher as a transmitter of that knowledge, and the student as a passive receptor of the knowledge transmitted. The act of transmission and reception of knowledge takes place within a very rigid classroom structure as will be explained shortly.

Moreover, the purpose here is not to make a value judgment concerning the relative worth of the traditional approach as compared to the inquiry approach, but rather to examine the various aspects of each approach so that one may build a frame-of-reference on which to base decisions concerning the method best suited for his intended goal. If his

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[35] Paul F. Brandwein, "Observations on Teachers," The Science Teacher, 36, 2, (February, 1969), 38-40.

goal be to transmit a given body of knowledge, then he may decide that the traditional approach is best. But if his intent be to encourage the student to formulate and test hypotheses, and to view his discipline as a science involving the use of higher intellectual powers, then he may find that the inquiry approach is the best means to that end.

The traditional approach casts the teacher in the role of a "teller," a transmitter of factual knowledge. The established pattern requires the teacher to divide a body of factual knowledge into small parcels that are then transmitted to the student. He may perform his role by way of lecture, chalkboard-talk or lecture-demonstration. But the basic procedure seldom changes as the teacher continues to propagate words of "wisdom" across his desk or lectern. Thus, the teacher commands the "spotlight" at the front of the room; he plays a highly active role in a highly structured classroom.

The students in a classroom that utilizes the traditional approach are generally seated at their desks where they are expected to act as passive receptors of factual knowledge. They listen, record on paper, read from a textbook and occasionally ask or attempt to answer a question if called on. The discussion in such a classroom is teacher-initiated and controlled so that it follows a teacher-student, teacher-student, teacher-student type of pattern (Figure 2-2). Thus, the students in the classroom that employs the traditional approach are cast in the role of passive learners, constantly manipulated by the teacher's commands.

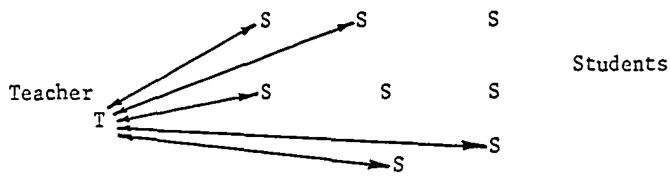

Figure 2-2. Pattern of discussion in the traditional approach of learning and teaching.

Evaluation of students' performances in the traditional approach places great emphasis on the ability to memorize and recall knowledge concerning the products of science. (The phrase "products of science" is used here to refer to the relatively static body of facts.) The process of science--the how and why of science--is seldom mentioned. Consequently, the student learns to think of science as a body of facts and terms, rather than a process involving hypotheses, data collection and analysis, experimenting, trials and errors, blind alleys and much creativity.

Teachers continue to teach as they were taught. They learn that a teacher must prepare for a classroom presentation by memorizing a body of content the night before the class and then present the content as if they remembered it since their undergraduate days. They then administer a test--difficult enough to tax the memory of a professional--which requires the student to regurgitate the teacher's presentation. Thus, the teacher omits the process of science and merely transmits the products of science, and thereby, unknowingly, conveys a distorted image of science to his students.

The student in the traditional approach is presented with a "packaged" problem and answer without the process of science, and then coerced to memorize it for recall on an examination (Figure 2-3). The

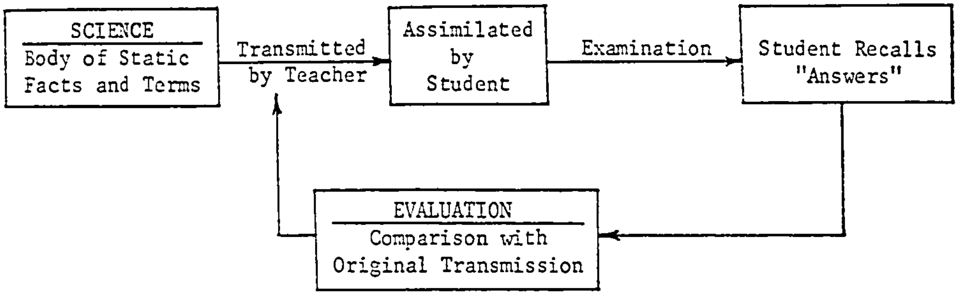

Figure 2-3. Evaluation in the traditional approach to learning and teaching.

evaluative procedure consists of comparing the student's answer on an examination with the answer provided by the teacher. If the two answers correspond, the student passes, otherwise he may fail.

One pole of the learning-teaching spectrum (Figure 2-4) is marked by the traditional approach which is characterized by an active teacher, a passive student and emphasis on products of science. The other pole is the inquiry approach which is characterized by an active student, passive teacher and emphasis on the process of science.

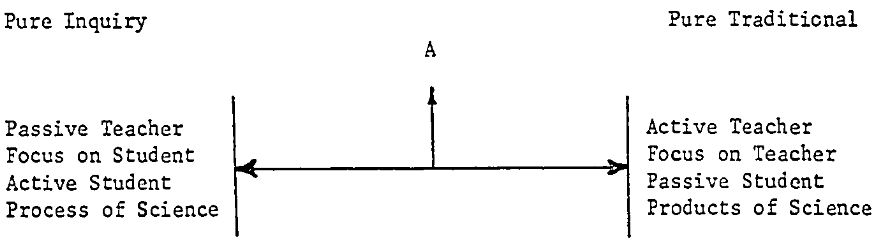

Figure 2-4. The learning-teaching spectrum indicating the characteristics of the polarized positions.

The role of the teacher in the inquiry approach to learning and teaching is passive in the traditional sense in that he seldom lectures, works at the chalkboard or commands the center of attention in the classroom. He is, however, active in that he creates an environment that is conducive to inquiry. He provides the necessary materials and facilities for inquiry. If necessary, he helps the student to isolate a problem. He acts as a guide and resource person for the student, he is present to help the student when help is needed, and at times he even invents concepts, otherwise he tends to remain in the background.

The student is the focus of attention in the inquiry type classroom. He interacts with the total environment as he explores, at times to delineate a problem as he views it, at times to pursue an investigation in an atmosphere where there are no "right" or "wrong" answers, only acceptable and unacceptable answers as the student sees and interprets his data. In other words he makes discoveries of his own. Thus, the student is given maximum opportunity to practice and evaluate strategies of data collection and analysis, and to examine each situation in terms of the variables and their interrelatedness. The student is encouraged to experiment and test hypotheses at every possible opportunity. Compared to the deskbound, passive student of the traditional approach, the student in the inquiry classroom is highly active in the learning process.

The evaluative process in the inquiry approach stresses the point of consistency between the problem, the process, and the product or solution (Figure 2-5). After delineating a problem himself or with the teacher's help, the student becomes involved in observation, measurement, data collection and analysis, experimentation and much fumbling as he

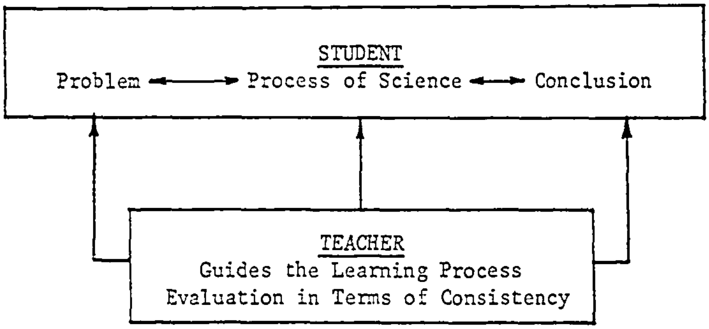

Figure 2-5. Evaluation in the inquiry approach of learning and teaching.

works toward a solution or conclusion. He may find that there is no solution, or he may suggest an explanation. The degree to which the student's conclusion is consistent with the problem and the process will determine the outcome of the evaluation. If the teacher detects inconsistencies between the problem, process and conclusion, he may question the student or suggest that the student attempt a similar problem under different conditions to check his results. Notice that the process is carried out by the student, and this is a major point of difference between the inquiry and traditional approaches, for it is the process that provides the learner with an opportunity to use higher levels of his rational powers.[36]

In differentiating between the inquiry approach and the traditional approach, the degree to which the student is active, and consequently the degree to which the teacher is inactive, is paramount. The teacher in the inquiry type classroom must relinquish most of his control and

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[36]Educational Policies Commission, The Central Purpose of Education. Washington, D. C.: National Education Association, 1961, p. 5.

position of attention in order to provide experiences that actively involve the student. Hunt points out that unless teachers have received special preparation, they are unwilling to accept a position of lower control, power, and prestige. Hunt states:

> ...there is the traditional desire of teachers for an orderly classroom and for control of the educational process. The influence of Rousseau, Pestalozzi, and Froebel had already helped to call into question this traditional desire for control.... The role of the teacher was limited to that of observer-helper of the children in their spontaneous efforts to cope with didactic materials. One gleams that this demotion was irritating to many teachers with other than Montessori training and indoctrination, and I believe this irritation persists among teachers today.[37]

But one must remember that although proponents of the inquiry approach advocate freedom for students to actively participate, they do recognize the need for the teacher to exert subtle control or guidance as required. The key term is "balance". The teacher must know when to stay out of the student's way and when to help. Dewey summarized his views on this as follows:

> It is possible of course to abuse the office, and to force the activity of the young into channels which express the teacher's purpose rather than that of the pupils. But the way to avoid this danger is not for the adult to withdraw entirely. The way is, first, *for the teacher to be intelligently aware* of the capacities, needs, and past experiences of those under instruction, and secondly, to allow the suggestion made to develop into a plan and project by means of further suggestions contributed and organized into a whole by the members of the group. The plan, *in other words, is a cooperative enterprise*, not a dictation.[38]

Moreover, it should be understood that activity per se is not

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[37]J. McV. Hunt, "Introduction: Revisiting Montessori," in The Montessori Method, by Maria Montessori (New York: Schocken Books, 1964), p. x.

[38]Dewey, op. cit., pp. 71-72.

sufficient for intellectual development. "The student does not learn just by being brought into contact with things."[39] The physical action of the student must be accompanied by intellectual activity; "freedom of outer movement is a means, not an end."[40] Piaget states:

> There are, in fact, two kinds of experience which are psychologically very different and this difference is very important from the pedagogical point of view .... First of all there is what I call physical experience, and, secondly, what I call logical-mathematical experience.[41]

Physical experience is the interaction between the student and physical objects. This type of activity per se does not constitute learning. The student must interact with the physical objects in such a way that he gives consideration to his actions; e.g., he must make observations, isolate variables, analyze relationships and attempt to predict an answer to the question, "If I do this, it follows that the result should be ..." Piaget continues:

> It is the total coordination of actions, actions of joining things together, or ordering things, etc. This is what logical-mathematical experience is. It is an experience of the actions of the subject, and not an experience of objects themselves. It is an experience which is necessary before there can be operations [thinking]. Once the operations have been attained this experience is no longer needed and the coordinations of actions can take place by themselves in the form of deduction and construction for abstract structures.[42]

Perhaps the greatest error committed by the teacher in the traditional classroom is the overemphasis on verbalism without prior activity.

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[39]B. F. Skinner, The Technology of Teaching (New York: Appleton-Century-Crofts, 1968), p. 154.

[40]Dewey, op. cit., p. 61.

[41]Jean Piaget, "Cognitive Development in Children: Development and Learning," Journal of Research in Science Teaching, 2 (3, 1964), 179.

[42]Ibid., p. 180.

Without the necessary experience, the student learns to verbalize the teacher's "right" answer or memorizes a passage from the textbook. The teacher too often makes the mistake of equating verbalization to understanding. There can be no guarantee that experience will be accompanied by logical thought and understanding; however, verbalism without the necessary earlier or concomitant experience can only result in the most superficial form of learning. Piaget believes that adults as well as children can learn better by doing things than by being told about them; if they read about it, it will be deformed, as is all learning that is not the results of the subject's own activity.[43]

In summary, learning by inquiry is characterized by an active student, an emphasis on the process of science, and a relatively passive teacher who knows when to volunteer guidance and when to stay out of the student's way. At the opposite extreme, the traditional approach to learning is characterized by an active teacher, a passive student, and emphasis on the products of science. While these two approaches have been viewed as polarized positions for the purpose of discussion, one must realize that it is not a dichotomous relationship, but rather a continuum of various degrees of inquiry and traditional traits. Thus, it is conceivable that a classroom operating on the inquiry mode will also incorporate lectures, chalkboard work and demonstrations--aspects that are mainstays of the traditional approach. Conversely, one should expect that the traditional type classroom may also incorporate activities that are common to the inquiry approach. The duration and frequency of various

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[43]Eleanor Duckworth, "Piaget Rediscovered," Journal of Research in Science Teaching, 2 (3, 1964), 172.

classroom activities will determine where on the learning-teaching spectrum (Figure 2-4) a specific class will be functioning. For example, if students are devoting fifty per cent of their classroom time inquiring into problems of interest to them and fifty per cent of their time listening to the teacher talk, the point which represents this mode of operation would be located midway between the poles of the learning-teaching spectrum.

Although the experimental laboratories in this study represent a marked departure from the traditional laboratories, ascertaining exactly where on the learning-teaching spectrum the mode of operation would be located is difficult. Based on the time devoted to lecture and independent student activity an estimate would place the mode of operation slightly left of center.

Review of Related Research

A search of the research literature indicated that virtually no work had been done involving the use of inquiry in the introductory geology laboratory programs. There existed, however, several studies that dealt with inquiry in physics, chemistry, and biology laboratories. Although the concepts and content of those disciplines represented problems that were quite different from those that one would expect to encounter in an introductory geology laboratory course, there were areas of similarities and a review of the studies was helpful in providing some insights into the application of inquiry to laboratory sciences in general.

Riggs[44] did a comparative study of two methods of teaching

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[44]Virgil Maynard Riggs, "A Comparison of Two Methods of Teaching College General Chemistry Laboratory," Dissertation Abstracts, University Microfilms, Inc., 1962, XXIII pp. 165-67.

college general chemistry laboratory in an attempt to assess their relative effectiveness in respect to improvement in one's problem-solving ability. He worked with two classes of beginning general chemistry students for one semester. The control group used the traditional laboratory manual, whereas the experimental group attempted to solve research-like laboratory problems without the use of a laboratory manual. He was unable to detect a significant difference with respect to improvement in problem-solving ability between the group taught by the traditional method and the group taught by the problem-solving method.

Rainey[45] studied the affects of two laboratory approaches on the achievement of high school chemistry students. Four classes were utilized in the study and all classes received the same type of lecture-discussion portion of the course. One-half of the number of students in each class received the traditional, highly directive, laboratory manual approach, whereas the other half of each class was simply given a problem to solve without any directions concerning procedures. The study extended over an entire school year.

Rainey found that a slight non-significant difference (.05) occurred between groups as measured by a test on facts and principles of chemistry. On a performance test that required both groups to utilize laboratory apparatus to solve a problem, the experimental group scored significantly (.05) higher than the control group. Rainey did point out that the performance test favored the experimental group since this was the mode of study they had been practicing.

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[45]Robert G. Rainey, "The Effects of Directed Versus Non-Directed Laboratory Work on High School Chemistry Achievement," Journal of Research in Science Teaching, III, 4, 1965, 286-92.

Montague[46] conducted a research study similar to Rainey's earlier investigation. Montague's study involved students enrolled in a college freshman level chemistry course oriented toward general education. He was interested in determining whether problem-solving abilities could be developed in a general chemistry laboratory. The control group worked with the usual laboratory manual of experiments, while the experimental group was provided with a series of problem-solving experiences that involved open-ended experiments. The investigation was carried on for a ten-week quarter term.

Evaluation based on statistical comparisons of students' performance on pretest and post-tests produced the following results:

1. No significant differences (.05) were found between the groups as determined by A Test of Aspects of Scientific Thinking[47] as used to measure the growth of students' ability in dealing with general problems of a scientific nature, and an investigator-constructed achievement test in chemistry.

2. Significant differences in favor of the experimental group were found between the groups as determined by a laboratory performance test that was constructed by Montague, and the Watson-Glaser Critical Thinking Appraisal at the .01 and .05 levels, respectively.

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[46]Earl J. Montague, "An Attempt to Appraise Whether Problem-Solving Abilities can be Developed in a General Chemistry Laboratory," The Science Teacher, 31, (March, 1964), 37-38.

[47]Mary Alice Burmester, "The Construction and Validation of a Test to Measure Some of the Inductive Aspects of Scientific Thinking," Science Education, 37 (March, 1953), 131-40.

The significant difference (.01) between groups as determined by the laboratory performance test supported the hypothesis that problem-solving abilities can be developed in a general chemistry laboratory course through the use of open-ended experiments. Rainey, however, pointed out earlier that the performance test favored the experimental group since that was the mode of study they had been practicing.

Encouraged by Montague's work, Montague and Ward[48] felt that the transfer of the outcomes from an open-ended chemistry laboratory experience could be more readily observed if a longer treatment period were included. They conducted an investigation similar to Montague's earlier study, but instead of college students he involved high school students and allowed the experiment to extend over an entire academic year rather than only ten weeks.

Analysis of covariance of pretest and post-test scores indicated that there was no significant difference (.05) between the control groups and the experimental groups in terms of ability to think critically about problems in science, in everyday living, and understanding of the nature of science. A significant difference (.05) in favor of the control group was found in the area of understanding major chemical principles.

Richardson and Renner[49] also conducted an investigation involving students in beginning college chemistry laboratory. They were interested

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[48]Earl J. Montague and Ray M. Ward, "The Development of Problem Solving Abilities in Secondary School Chemistry," Journal of Research in Science Teaching, 5, 4, (1967-68), 345-56.

[49]Verlin H. Richardson and John W. Renner, "A Study of the Inquiry-Discovery Method of Instruction in College Chemistry Laboratory," Journal of Chemical Education, 47 (January, 1970), 77-79.

in assessing the relative effectiveness of inquiry instruction and traditional instruction in promoting favorable attitudes and understandings in chemistry. The control group employed a conventional laboratory manual while the experimental group concentrated on inquiry-type activities designed by the investigator. The investigation extended over three semesters with different students involved each semester.

Their results favored the use of inquiry-type chemistry activities as significantly (.05) more effective in stimulating understandings in chemistry. Statistical comparison of pretest and post-test scores on an investigator-constructed test on understanding chemistry yielded significant differences (.05) between the control and experimental groups. Significant differences were also found on all eight experiments conducted by control and experimental groups. Subjective analysis by an outside observer supported a favorable attitude toward the inquiry approach as voiced by the majority of those interviewed.

Schefler[50] did a comparative study between an inductive laboratory approach and a traditional lecture-demonstration approach to teaching college freshman biology. He randomly assigned two instructors to four classes, two classes per instructor, so that each instructor taught a control group and an experimental group. All groups were pretested prior to the experiment and post-tested at the end of the ten-week unit in genetics. Schefler concluded that:

> In terms of the genetics instrument, the F tests for method and interaction were non-significant, but the F value for

[50]William Carl Schefler, "A Comparison Between Inductive and Illustrative Laboratories in College Biology," Journal of Research in Science Teaching, 3, 3, (1965), 218-23.

instructor was significant at the .05 level.

> The TOUS [Test on Understanding Science] data yielded non-significant F values for method and instructor effects, but the F value for interaction was significant at the .05 level.
>
> Neither the Kuder Preference Record data nor the semantic differential data yielded significant F values for any of the three null hypotheses relating to method, instructor, or interaction.[51]

Coulter[52] investigated the relative effectiveness of three approaches to teaching ninth grade biology laboratory students. The first approach, the inductive laboratory, allowed the students to develop and implement their own experiments, gather data and generalize from the data. A second approach, inductive demonstration laboratory, varied from the inductive laboratory treatment only in that the experiment was teacher-demonstrated. In third approach, the deductive laboratory, the teacher presented principles in biology and then directed the students to carry-out a proof. After conducting the experiment for 22 weeks and analyzing the data, Coulter concluded that:

> The inductive treatment produced significantly greater attainment of attitudes of science. The inductive treatment emphasis upon designing experiments and analyzing the data in no way distracted from the student's ability to learn and apply facts and principles. No method of instruction was found to be more effective with any particular ability range as opposed with respect to any outcomes of instruction. For no outcome was there a significant difference in favor of the deductive laboratory treatment. The students in the laboratory

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[51]William Carl Schefler, "A Comparison Between An Inductive Laboratory Approach and a Traditional Lecture-Illustrative Laboratory Approach to Teaching College Freshman Biology," Dissertation Abstracts, University Microfilms, Inc., XXVII, 1966, pp. 692A-93A.

[52]John C. Coulter, "The Effectiveness of Inductive Laboratory, Inductive Demonstration, and Deductive Laboratory in Biology," Journal of Research in Science Teaching, 4, 3, (1966), 185-86.

treatments reacted more positively to their instruction than did the students receiving the demonstration treatment.[53]

Shannon[54] compared two laboratory methods of teaching college biology; a conventional recitation laboratory and an integrated independent study method that utilized a mimeographed laboratory guide to integrate laboratory activities involving 23 hours per week of open laboratory and fifteen-minute lessons on audio tape. The experiment continued for one academic year. The data on five of the six tests used in the study showed no significant difference between groups. Only one test, the investigator's test on knowledge of facts and principles in college biology, yielded a significant difference (.05) and that favored the conventional laboratory approach.

Zingaro[55] worked with 793 sophomores enrolled in college physical science. He was interested in comparing an inductive method and the traditional method of teaching college physical science in the laboratory. He found significant differences (.05) in favor of the inductive method as determined by student scores on the Physical Science Critical Thinking Appraisal. A significant instructor effect was also discovered. No other differences between the groups were detected.

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[53]Ibid., Dissertation Abstracts, University Microfilms, Inc., XXVI, (Numbers 7-8, 1965), 4494.

[54]Harold Kenneth Shannon, "A Comparison of Two Laboratory Methods of Teaching Biology: A Conventional Recitation and Laboratory Versus an Integrated, Independent Study Approach," Dissertation Abstracts, University Microfilms, Inc., XXIX, 1969, 4043-B.

[55]Joseph Samuel Zingaro, "An Experimental Comparison Between Two Methods of Teaching College Sophomores the Interrelationship of Physiochemical Principles in Physical Science," Dissertation Abstracts, University Microfilms, Inc., XXVII, 1966, 1004-A.

Parke[56] conducted a study, similar to Zingaro's study, involving students enrolled in college general physics. He found:

> The inductive laboratory method proved to be superior with respect to the Physical Science Critical Thinking Appraisal.
>
> The effect due to his instructor differences was at least as important in terms of student achievement as the effect due to differences in teaching methods.
>
> The evidence indicated no significant relationship between a student's ability to think critically in physical science and his ability to think critically in nonscience areas.
>
> No evidence was found to indicate that the inductive laboratory method is less effective than the traditional laboratory method with reference to student achievement in college physical science.[57]

In summary, the above cited research indicated that findings concerning the definite superiority of the inquiry approach to learning and teaching in science laboratories were inconclusive. Although many studies indicated significant differences in support of the inquiry approach, other studies showed no significant differences between inquiry methods and traditional methods of learning and teaching science in the laboratory. The majority of the aforementioned studies, however, favored inquiry or showed no dignificant difference; only one study[58] supported a significant difference in favor of the traditional approach. This suggested a definite trend in support of inquiry, for there was a strong logical basis in favor of an approach that emphasized science as a process

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[56]Edward C. Parke, Jr., "Open-Ended Versus Conventional Experiments in General Physics, An Exploratory Study," Dissertation Abstracts, University Microfilms, Inc., XXVIII, 1968, 3569-A.

[57]*Ibid.*

[58]Shannon, op. cit., p. 4043-B.

involving higher levels of intellectual activity, stressed student involvement, and proved to be equal to or better than the traditional approach in developing favorable student attitudes and mastery of content. This was true because the traditional approach had content mastery as its prime objective and utilized all the best telling techniques which could be mastered to achieve that objective.

CHAPTER III

PRELIMINARY PROCEDURES

The evaluation, formulation and background of the problem as delineated in Chapters I and II did not take place in isolation from each other, nor did they constitute a sufficient basis from which a study may be properly designed. Several related, preliminary tasks had to be accomplished in order to place the problem in sharper focus and devise ways and means of attacking it. This meant that each phase of the problem had to be closely scrutinized and analyzed in terms cf its characteristics and how they related to other phases of the problem. More specifically, one had to be concerned with the role and views of the faculty and graduate assistants, background of the students, and the nature of the laboratory session, both its mechanical and psychological aspects. On the basis of information gathered on the above phases, one had to attempt to answer the question: What changes, which would help to solve the identified problems, can be implemented in the laboratory, and how can the affects of the changes be measured and evaluated?

This chapter explicates the procedures and results of the preliminary activities. The first two sections, Survey of the Faculty and Graduate Assistants, and Survey of Students' Background, deal with information that will be beneficial primarily to personnel in the School of Geology and Geophysics in that these sections are concerned with the broader aspects of the Introductory Geology Program. Inclusion of the procedures and results here, however, do help to place the main problem in its proper perspective. The section on Instructing in the Laboratory and Designing Laboratory Activities delves into the isolation of specific problems and designs for their correction. The last section, Construction of Measuring Instruments, explains the procedures followed in the development of two tests to measure achievement in geology content, and student attitude toward the laboratory section, respectively.

Survey of the Faculty and Graduate Assistants

The faculty of the School of Geology and Geophysics carry the prime responsibility for the design and implementation of the Introductory Geology Program. All aspects of the program, such as textbook, laboratory manual and materials, and the mechanics of scheduling and operating the program are subject to faculty discussion and approval prior to adoption. Furthermore, the faculty is the only quasi-permanent group in possession of knowledge concerning the past and present nature of the Introductory Geology Program. Thus, they were viewed as a prime source of information relating to the overall problem.

In an attempt to draw on the reservoir of faculty information, a two-part survey was conducted. The first part consisted of informal interview-discussion type interactions between individual faculty members and this investigator. These interactions ranged from a brief ten minutes in duration to more than an hour, depending on the degree of interest showed by the professor. Based on eleven individual contacts, the following general views were listed as contributing factors concerning the status of the Introductory Geology Program.

(1) The laboratory program was vital to the graduate program in that it provided a basis for graduate assistantships.

(2) Although many graduate assistants performed well, the inexperienced and transient nature of the graduate assistants was responsible for some of the problems associated with instruction in the laboratory classes.

(3) The graduate assistants needed more and closer supervision.

(4) Some professors refused to gear their lecture schedule to that of the laboratory section; thereby, reducing the correlation between the two sections.

(5) Each laboratory section was composed of students from several lecture sections. While this facilitated flexibility in scheduling, it also contributed toward reducing correlation between the lecture and laboratory sections.

(6) Some professors disapproved of the recent adoption of a different laboratory manual while others viewed it favorably.

(7) Few professors had worked with the present laboratory program.

(8) More than 95 percent of the students were other than geology majors, and this was associated with low interest on the part of many students.[59]

(9) Most of the professors agreed that general concepts should be stressed, rather than terminology and isolated facts.

(10) One professor produced figures to show that enrollment in Physical Geography had increased over the past three years while enrollment in Introductory Geology had been decreassing, despite increased enrollment at the University.

The responsibility for the instruction in the laboratory sections of the Introductory Geology Program rested on the graduate assistants.

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[59]Since more than 95 percent of the students were other than geology majors, one wonders if the promotion of favorable student attitudes might be equally or more important than content mastery in geology, especially in view of the present environmental crisis.

They were generally graduate students who were completing degree requirements for the Master of Science in Geology or the Ph. D. in Geology, although the more advanced Ph. D. candidates frequently served as special instructors and conducted lecture sections. The label "graduate assistant" will be used here to refer to both the laboratory instructors and the special instructors. Many of the graduate assistants were well experienced laboratory instructors, having served in that capacity for three or more semesters, and some were experienced in both the laboratory and the lecture sections. Thus, they were recognized as a favorable source of information that would blend the views of both student and instructor, and therefore, were included in the survey.

The first part of the survey of the graduate assistants consisted of informal, interview-discussion type sessions, just as it did with the faculty. The following comments are representative of the more experienced graduate assistants.

(1) Some of the laboratory exercises as found in the manual were too difficult or boring for the students, especially the non-majors, so parts of the laboratory exercises were omitted or replaced by "handout" exercises.

(2) Students became tired of the emphasis on map reading.

(3) Since students came from different lecture sections where different schedules were followed, the laboratory instructors found that explanations usually meant repetition for some, while failure to explain meant omission for others.

(4) It was customary to start each laboratory period with a lecture that ranged from one-half-hour in duration to as much as an entire period, depending on the exercise and the laboratory instructor.

(5) Although most graduate assistants voiced an attempt to reduce terminology and isolated facts in favor of principles, one person did feel that more attention should be given to terminology and facts so that the students would be better prepared to go on in geology.

The second part of the survey was concerned with the goals of the Introductory Geology Program. What were the faculty's views concerning the major goals of the program? Survey sheets (Appendix A) listing 26 statements of goals for the Introductory Geology Program were distributed to the faculty and experienced graduate assistants. Each person was asked to categorize his reaction to each statement as "disapprove", "approve" or "undecided" and to rate his response on a scale of from zero for "disapprove" to five for strongly "approve" with no rating for "undecided". In addition, each respondent was asked to add suggestions and comments concerning the overall area of goals. Ten faculty members and seven graduate assistants responded. The results of the survey were tabulated as shown in Table 3-1.

Examination of Table 3-1 and the related Figure 3-1 revealed some interesting relationships. The wide range of responses for any given statement indicated disagreement concerning the value of any given goal. Only statement number six, the first ranked statement by both faculty and graduate assistants, and statement number 13, the lowest ranked statement, showed high agreement among those who responded. The mean ratings, however, indicated more agreement between faculty and graduate assistants, even though there were some conspicuous differences as indicated by peaks on Figure 3-1 for statements numbers 19, 21, 14, 8 and 10. Statement number 19, "to provide the student with the opportunity to develop problem solving skills through the process of inquiry," was ranked sixteenth by the faculty while the graduate students ranked it third. Another interesting point was that statement number six, "to give the student who takes no further courses in geology an opportunity to gain an understanding of his earthly

TABLE 3-1

GOAL-RANK, AND NUMBER AND MEAN INTENSITY OF RESPONSES*

STATEMENT OF GOAL	Responses Number and Intensity Disapprove ← → Approve 0	1	2	3	4	5	Mean	Rank
1. To help the student gain an understanding of the history of the earth.		1		4	1	4	3.7	6
			1	1	2	3	4.0	6
2. To help the student understand the work of the geologist.			3	3		3	3.0	9
	1		1	4		1	2.8	9
3. To help the student develop an understanding of the evolution of thought that influenced geology.	1	2	2	2		3	2.7	12
	1	3	1		1		1.5	14
4. To provide the student with an opportunity to grow intellectually.		1			3	3	4.0	3
			1		1	5	4.4	2
5. To help the student understand unsolved problems in geology and their concomitant inherent difficulties.	1		2	2	1	3	3.2	8
	1	1			3	1	3.0	9
6. To give the student who takes no further courses in geology an opportunity to gain an understanding of his earthly environment and its limitations.			1		1	8	4.6	1
					2	4	4.6	1
7. To help the student gain as much factual knowledge and terminology in geology as is possible during the relatively short period of one semester.	6			1	1	1	1.3	18
	3	2		2			1.1	16
8. To encourage the bright student to pursue the field of geology as a career.		2	2	2	2	1	2.8	11
			2		1	4	4.1	5

*Each Statement of Goal is associated with two rows of data. The upper row is faculty data and the lower row is graduate assistant data.

TABLE 3-1 - Continued

STATEMENT OF GOAL	Responses Number and Intensity: Disapprove 0	1	2	3	4	Approve 5	Mean	Rank
9. To help the student gain an understanding of the earth's natural resources, their uses and their limited amounts.		2	1	4	2	1	2.9	10
			2	1	3	1	3.4	7
10. To prepare the student for more advanced study in geology.	1	1	2	3		2	2.7	12
			1		3	1	3.7	7
11. To meet the needs of the liberal arts students.	1	1		1		7	3.9	4
	2		2		1	1	2.2	12
12. To help the student to understand the relationships between geology and man.	1	2	2		1	5	3.3	7
			1	1	2	3	4.0	6
13. To help the university screen out low ability students.	9		1				0.2	20
	5	1	1				0.4	18
14. To help the student grow in the knowledge and use of scientific procedures in problem-solving.	1	2	1	4	1	1	2.5	13
				2	1	3	4.2	4
15. To provide the student with an opportunity to study earth science; i.e., geology and related fields--climatology, soils, meteorology, oceanography and astronomy.	3	1		4		2	2.3	14
	1	1	1	2		2	2.7	10
16. To guide the student in the formulation of reasonable generalizations from specific data of an experiment.	1	3	2	2	2		2.1	15
				2	1	1	3.4	8
17. To help the students grasp an understanding of the "structure" of geology; i.e., the broad concepts and relationships that thread through geology and related fields as supported by facts.		2		1	1	5	3.8	5
			1		3	3	4.0	6

TABLE 3-1 - Continued

STATEMENT OF GOAL	Responses Number and Intensity Disapprove ←→ Approve 0	1	2	3	4	5	Mean	Rank
18. To help the student gain an understanding of the contributions made by the great pioneers in geology.	3	3		3	1		1.6	17
	2	2	2	1			1.3	15
19. To provide the student with the opportunity to develop problem-solving skills through the process of inquiry.	1	3		4			1.9	16
				1	3	3	4.3	3
20. To help the student understand the environmental problems created by our society, and encourage him to take an active interest in their solution.	2		1	2	2	2	2.9	10
	1		2	2		1	2.5	11
21. To help the liberal arts student gain a better understanding of science so that he may better close the communications gap between the arts and sciences.	3		2	3	1	1	1.7	17
			1	1	1	4	4.0	6
22. To help the student understand the forces and processes that shape the crust of the earth.	1				3	5	4.1	2
			1		1	5	3.7	7
23. To help the student see geology as a human activity viewed in a historical and philosophical perspective.	1	2	1	2		1	2.1	15
			2	2			2.5	11
24. To help the student develop skill in the rudimentary techniques utilized in geology; i.e., rock and mineral identification, and reading of topographic maps.		2	3	1	1	3	3.0	9
	1	1		1	1	3	3.0	9
25. To help the student meet his science requirement for his degree program.	4	1	1			1	1.1	19
	2	3	1				0.9	17
26. To provide the student with an opportunity to utilize quantitative data (chemistry, physics and math) in the solution of elementary problems in geology.	1	3	2	2	1		1.9	16
	2	2	1	1	1		1.6	13

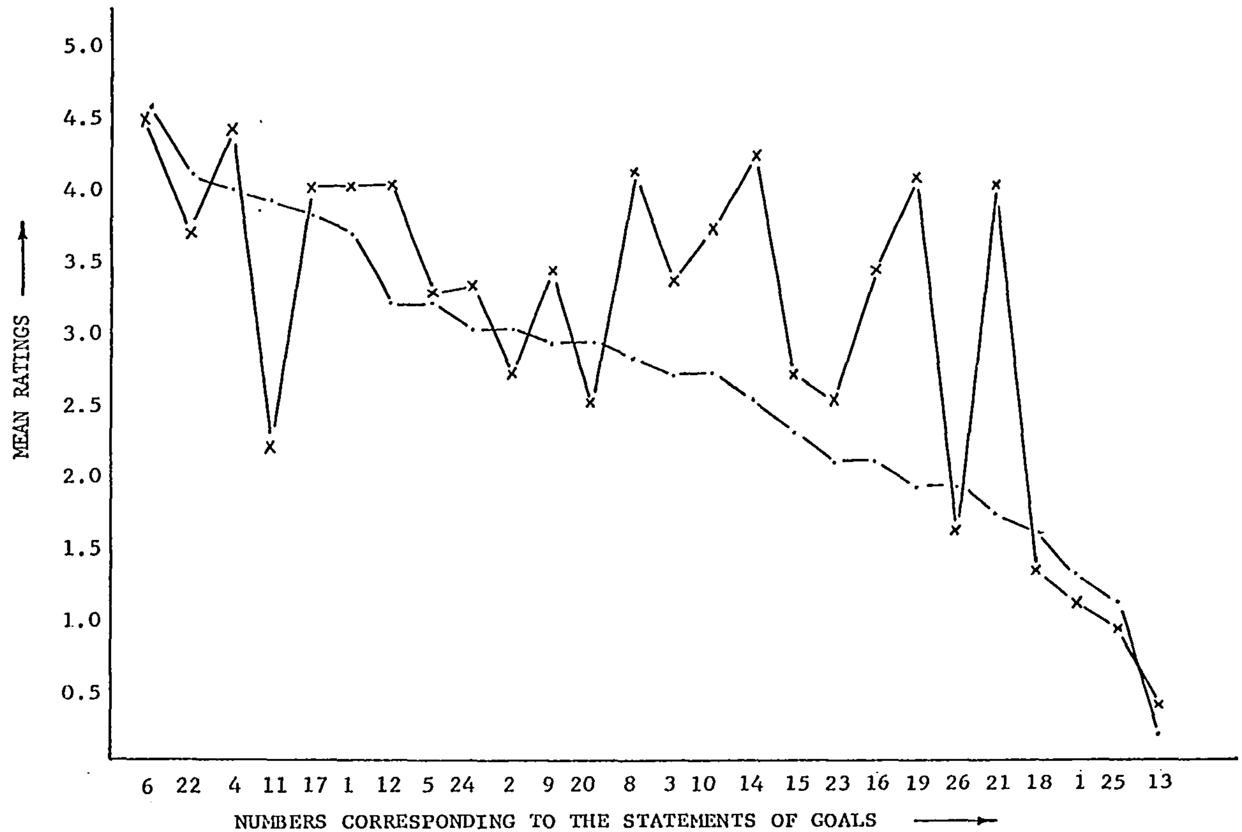

Figure 3-1. Mean Ratings of Goals by Faculty (•) and Graduate Assistants (x)

environment and its limitations," was ranked first by both faculty and graduate assistants, but statement number 20, "to help the student understand the environmental problems created by our society, and encourage him to take an active interest in their solution," was only ranked tenth and eleventh.

One must bear in mind that the above procedures and information gathered were not intended to serve as a means to potent conclusions concerning faculty and graduate students' attitudes toward the Introductory Geology Program. Rather, one hoped that the description of procedures and the information gathered would be helpful in aiding interested personnel in the School of Geology and Geophysics by providing an intuitive basis for further examination and subsequent improvement of the Introductory Geology Program. From this investigator's viewpoint, such procedures and information served toward a better perspective of the total introductory geology problem as it related to directions for improvement and to the main inquiry hypothesis of this study.

Survey of Students' Background

Much discussion has recently taken place in the geologic community concerning the Introductory Geology Program in institutions of higher learning throughout the United States.[60, 61, 62] Educators,

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[60]William B. Hambleton, "The Status of Undergraduate Geological Education: A GEO-Study Report," Geotimes, VIII, no. 5, Part B (January-February, 1964), 2-3.

[61]William D. Romey, "Reflection on Undergraduate Goals," ESCP Newsletter, 20 (October, 1969), 1, 4-5.

[62]Raymond Pestrong, "Metageology: Science Plus Aesthetics," Journal of Geological Education, XVI, no. 4, (October, 1968), 37-38.

primarily those in the Geosciences, are asking questions concerning the nature of the Introductory Geology Programs. "Who are the students being served and how can we best serve them?" "Would a cultural course better meet the needs of these students or should we become more quantitative with greater emphasis on mathematics, physics and chemistry?" "What are the merits in having one course for everyone as opposed to separate courses for majors and non-majors?" "Should prerequisites be required; if so what should they be?" The answers to many of these questions will be based on an understanding of the nature of the student and the goals to be achieved. The goals, as determined by the faculty and the graduate assistants have been stated earlier; this section deals with data on the background of the student.

In order to obtain data on the background of the students enrolled in the Introductory Geology Program (Geology I) at The University of Oklahoma, a survey was conducted during the 1968-69 Spring Semester. The survey consisted of a questionnaire (see Appendix B) which asked the students to respond to questions in three categories; general background, high school information, and college information. To insure uniformity in administration, all of the questionnaires were distributed and collected by this investigator during the normally scheduled lecture sections. A total of 358 questionnaires were processed.

Table 3-2 displays the data yielded by the processed questionnaires. When examining the data, one should bear in mind that the majority of the freshmen had completed the 1967-68 Fall Semester prior to the survey. Item 8 received more than one response from each student, so the calculated percentage was greater than 100 percent. The difference between the total number of questionnaires processed and the total responses to a given item was equal to the number of students who failed to respond to that item. All percentages, however, were based on the total number of questionnaires processed since the number of students who failed to respond to each item was small.

Examination of the data in Table 3-2 helped to portray the "average" student enrolled in Geology I. He was a freshman or sophomore who made his own decision to attend college, but he was not exactly sure of his objective; however, he indicated a preference for those areas other than mathematics and science. His high school academic record showed that he was well prepared in algebra, geometry, and biology; fair in chemistry and general science; and poorly prepared in earth science, trigonometry, and physics. He enrolled in Geology I to meet his science requirement. Upon enrollment in college, he tended to avoid courses in physics, chemistry, and mathematics.[63]

Instructing in the Laboratory and Designing Laboratory Activities

Many of the aspects of the problem began to form a coherent whole when this investigator assumed a position as an instructor in the Introductory Geology Program during the 1967-68 Spring and 1968-69 Fall Semesters prior to the actual experiment in the 1968-69 Spring Semester. The experience proved to be invaluable because it afforded a first-hand view of the problems that existed in the laboratory sections, and thereby formed a basis for the design and trial implementation of ideas and

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[63]It would be interesting to speculate on why a student, despite his fair high school background, tended to avoid physics, chemistry, and mathematics in college.

TABLE 3-2

NUMBER AND PERCENTAGE OF RESPONSES

Item	Responses Type	Responses Number	Percentage
1. Total number of questionnaires processed		358	100.0%
2. Number of male students		187	52.7%
3. Number of single students		316	89.0%
4. Number of married students		29	8.2%
5. Resident of Oklahoma		221	62.2%
Out of State		122	34.4%
6. If you are not planning on majoring in Geology, indicate why not by checking any of the following which may apply:			
a. Not interested in occupational or professional career		99	27.7%
b. Not enough challenge in Geology		16	4.5%
c. Not enough job opportunity in Geology		28	7.9%
d. Enthusiasm dulled by this or previous Geology		47	13.2%
e. Not interested in science		72	20.3%
7. Is knowledge of geology useful to the average citizen?	Yes	271	76.3%
	No	75	21.1%
8. Why are you taking Geology?			
a. To meet my science requirement		288	81.1%
b. I thought it would be interesting		144	40.6%
c. It is generally considered to be an easy course		17	4.8%
HIGH SCHOOL DATA			
9. Approximate size of High School you graduated from:			
a. under 250		22	6.2%
b. 250-500		53	14.9%
c. 500-1000		50	14.1%
d. 1000-2000		101	28.4%
e. 2000-3000		82	23.1%
f. over 3000		36	10.1%

TABLE 3-2 - Continued

Item	Responses Type	Number	Percentage
10. Have you ever taken an Earth Science course? (Astronomy, Geology, Meteorology, Oceanography, or Space Science)	Yes	48	13.5%
	No	298	83.9%
11. Did the earth science course include laboratory exercises?	Yes	20	5.6%
	No	26	7.3%
12. Did you participate in any of the following courses in High School?			
a. HPP Physics	Yes	11	3.1%
b. PSSC Physics	Yes	49	13.8%
c. BSCS Biology	Yes	121	34.1%
d. CHEMS Chemistry	Yes	60	16.9%
e. CBA Chemistry	Yes	26	7.3%
f. ECCP Eng. Concepts	Yes	8	2.2%
g. IPS Physical Science	Yes	24	6.8%
h. SSSP Time, Space, Matter	Yes	1	0.3%
i. ESCP Earth Science	Yes	12	3.4%
13. Approximately how many years have you had in the following courses?			
a. Biology	0	24	6.8%
	1	262	73.8%
	2+	67	18.9%
b. Chemistry	0	96	27.0%
	1	226	63.7%
	2+	30	8.4%
c. General Science	0	49	13.8%
	1	194	54.6%
	2+	107	30.1%
d. Geology or Earth Science	0	285	80.6%
	1	44	12.4%
	2+	10	2.8%
e. Algebra	0	14	3.9%
	1	88	24.8%
	2+	250	70.4%
f. Trigonometry	0	174	49.0%
	1	159	44.8%
	2+	13	3.7%
g. Geometry	0	29	8.2%
	1	294	82.8%
	2+	29	8.2%
h. Physics	0	210	59.2%
	1	126	35.5%
	2+	7	1.9%

TABLE 3-2 - Continued

Item		Responses Type	Number	Percentage
i. No Physics or Chemistry			81	22.8%
j. No Trigonometry, Physics or Chemistry			64	18.0%
14. Your approximate overall senior high school grade standing (Grades 9-12)		A	72	20.3%
		B	202	56.9%
		C	72	20.3%
		D	3	0.8%
15. Did your parents graduate from high school?	Mother	(yes)	315	88.7%
	Father	(yes)	305	85.9%
COLLEGE DATA				
16. How certain are you of your college objective or major?				
a. Dead sure			113	31.8%
b. Pretty definite			154	43.4%
c. Have an idea			69	19.4%
d. Total blank			13	3.7%
17. Why did you come to college?				
a. Parental pressure			10	2.8%
b. Personal decision			290	81.7%
c. Other			39	11.0%
18. Classification				
a. Freshman			127	35.8%
b. Sophomore			120	33.8%
c. Junior			75	21.1%
d. Senior			23	6.5%
e. Unclassified			3	0.8%
f. Graduate			1	0.3%
19. College				
a. University College			144	40.6%
b. Arts & Sciences			179	50.4%
c. Education			7	2.0%
d. Engineering			1	0.3%
e. Law			0	0.0%
f. Pharmacy			2	0.6%
g. Fine Arts			1	0.3%
h. Graduate			0	0.0%

TABLE 3-2 - Continued

Item	Responses Type	Responses Number	Percentage
20. Principal College Objective or Major			
a. Art		6	1.7%
b. Biology		14	3.9%
c. Chemistry		7	1.9%
d. Dance-Drama		1	0.3%
e. Economics		13	3.7%
f. Education		13	3.7%
g. English		15	4.2%
h. Engineering		1	0.3%
i. Foreign Language		19	5.4%
j. Geography		1	0.3%
k. Geology		6	1.7%
l. Government		4	1.1%
m. History		11	3.1%
n. Home Economics		8	2.3%
o. Journalism		15	4.2%
p. Mathematics		12	3.4%
q. Music		1	0.3%
r. Physical Education		0	0.0%
s. Philosophy		2	0.6%
t. Psychology		20	5.6%
u. Pre-medicine		20	5.6%
v. Pre-law		11	3.1%
w. Sociology		10	2.8%
x. Physics		4	1.1%
21. Approximately how many semesters, college credit, have you had in the following courses (prior to this semester):			
a. Biology	0	194	54.6%
	1	90	25.4%
	2	36	10.1%
	3+	22	6.2%
b. Chemistry	0	185	52.1%
	1	97	27.3%
	2	34	9.6%
	3+	27	7.6%
c. Geography	0	318	89.6%
	1	17	4.8%
	2	2	0.6%
	3+	1	0.3%
d. Geology	0	281	79.2%

TABLE 3-2 - Continued

Item	Responses Type	Number	Percentage
	1	51	14.4%
	2	2	0.6%
	3+	2	0.6%
e. Mathematics	0	142	40.0%
	1	109	30.7%
	2	55	15.5%
	3+	39	11.0%
f. Physics	0	284	80.0%
	1	26	7.3%
	2	12	3.4%
	3+	15	4.2%
g. No Physics or Chemistry		165	46.5%
h. No Physics, Chemistry or Mathematics		83	23.4%
22. Rate Geology in terms of your desire to enroll for further courses. Use a one (1) to five (5) scale to indicate level of desire with 1 = No Desire, 2 = Little Desire, 3 = Medium Desire, 4 = Strong Desire, 5 = Very Strong Desire.	(1)	94	26.5%
	(2)	76	21.4%
	(3)	117	32.9%
	(4)	38	10.7%
	(5)	17	4.8%

activities to overcome specific problems as stated in this section. While it was a time for confirming some earlier views stated by faculty members and graduate assistants during the earlier surveys, it was also a time to disregard or modify preconceived easy solutions. For example, early plans for an unstructured laboratory were severely modified after several experimental classes.

It soon became evident that the central problem in the laboratory was created by the laboratory exercises. The primary drawback of the laboratory series was that it required the student to learn an average of 20 new terms per exercise and frequently asked the student to apply principles of which he had little or no understanding. As an example, the laboratory on volcanism asked the student to explain the origin of the broad-bottomed radial valleys along a crater rim as indicated on a topographic map, but it would be six more weeks before the student was introduced to concepts in glaciation. These exercises consisted of a series of eleven, relatively unarticulated, cookbookish, loose-leaf pamphlets. Each pamphlet constituted the work to be done during one laboratory period, and as such, it dictated content, and to a high degree, the procedure to be followed by the laboratory instructors and students. Furthermore, the laboratory instructors were advised to omit most of the quantitative sections of each laboratory exercise because it created difficulty for the students and efficiency of time demanded that some sections be omitted. Thus, except for the exercises on minerals and rocks, student activity was based on maps, especially topographic maps.

The laboratory instructor found himself in a difficult situation. The nature of the laboratory exercises demanded that the students bring a high understanding of principles and terms to the laboratory session, but students frequently came unprepared because they had not been exposed to the material in earlier lecture sections, or they had been exposed to it but failed to gain understanding. Since students came from several different lecture sections, each one commonly following a different lecture schedule. The laboratory instructor's presentation was viewed as repetition by those students who came prepared and as omission by those who, perhaps through no fault of their own, came unprepared and the instructor failed to provide an explanation of required background terms and principles prior to the laboratory activity. The instructor, however, invariably chose to lecture prior to the laboratory activity rather than undergo the exasperating experience of being asked the same question by several different students.

Although a lecture before the laboratory activity helped to reduce repetitious questions, it did produce a negative effect in that the instructor assumed the role of a "teller" or transmitter of information and the student remained a passive listener just as he did in the lecture section. The length of the lecture at the beginning of the laboratory session varied according to the laboratory exercise and the instructor, but it was not uncommon to devote the first hour to lecture. One lysiphobic instructor (one who is afraid of loose ends; generally one who equates telling to teaching) felt compelled to lecture on geologic structures for one and one-half laboratory periods (3 3/4 hours), during which the students were mainly passive listeners and note-takers. While this represented an extreme case, it did call attention to the difficulty encountered in preparing students to successfully attempt the laboratory exercises.

Examination of the situation revealed the following interrelated problems:

(1) The laboratory exercises demanded that the student have a wealth of information prior to attempting the exercises.

(2) The laboratory instructor lectured for too much of the 2½ hour laboratory period.

(3) The student was passive during the lecture portions of the laboratory periods.

(4) Laboratory materials were limited to minerals, rocks, and maps, but mostly maps.

(5) Lack of correlation between lecture sections and laboratory sections produced a wide range of student backgrounds.

(6) The laboratory exercises were isolated units rather than an articulated sequence.

In the initial attempts to solve the above problems, high hopes were placed on the implementation of an unstructured inquiry approach. This approach consisted of "stocking" the laboratory classroom with a maximum amount of materials pertaining to a phase of geology and then providing the student with a maximum amount of freedom to interact with the materials. For example, the unit on structures consisted of different materials grouped in various parts of the room for several activities. One corner contained commercial models showing a map view and cross section. Another corner contained some clay models of structure with extra clay and suggestions for building other models. The center of the room housed a large model that was painted and the students were asked to determine the structure from bits of information relating to surface features. In addition, color slides of geologic structures were available, small group discussions were encouraged, and everyone received copies of completed and partially completed paper "cutouts", diagrams of structural features that took on a 3-dimensional effect when cut and folded. The laboratory session began with a brief explanation of the many alternatives available and all students were asked to interact with the materials and each other with the intention of learning about structural geology.

The results were much less than spectacular, but they were to be expected. "Is this what you want?" asked one student. "Will we have this on an exam?" asked another student. "How long should we stay at each station?" "Are we being graded on this?" "What should I do after I looked at everything?" In short, most of the students wanted to be told exactly what to do, and since specific directions were withheld, they felt insecure and left well before the end of the period as they were free to do. Four students did stay till the end of the period and appeared to be working well.

Additional experimentation with the unstructured inquiry approach "captured" more students but most of them continued to flounder. It gradually became evident that twelve meetings during the semester would not be enough time to counter the conditioning effect of twelve years of traditional schooling. Consequently, each successive laboratory activity became increasingly structured to a point that struck a balance between the highly structured traditional laboratory approach and the unstructured inquiry approach. The result was a structured-inquiry approach--a middle-of-the-road position between the traditional approach and pure inquiry.

The design of the laboratory exercises underwent further test and modification during the 1968-69 Fall Semester. The final form was a series of twelve laboratory exercises (Appendix C) that exposed the student to essentially the same content areas as did the traditional laboratory series, but it was approached in a manner designed to overcome the drawbacks of the traditional laboratory series as delineated earlier. Each laboratory exercise began with a brief introduction by the instructor concerning an overview of the scheduled activities. The introduction was followed by an activity that involved the students, or where it was impossible to simulate the process indoors, movies and color slides were utilized to lay the basis for subsequent activity. Care was taken to insure that the majority of the questions on the laboratory sheets could be answered by most of the students. This was accomplished by utilizing questions that referred to the students' common laboratory experiences or references; e.g., laboratory activities, movies, stereo-photo descriptions, color slides and discussions.

The rationale behind the design of the laboratory exercises was that the first portion of the laboratory sessions be devoted to activities that would provide the basis for answering questions found in subsequent parts of the laboratory exercises; thereby reducing the dependence of the laboratory on the lecture sections, freeing the laboratory instructor and students from the necessity of long introductory lectures, allowing the student to play an active role and increasing the level of student success. In addition, the laboratory materials that were utilized went beyond the traditional minerals, rocks, and maps to include compression boxes, clay, stereophotographs correlated with topographic maps, models, movies, and color slides. Integration of content was attempted in two ways: (1) referral of concepts to earlier and/or later content areas; (2) use of take-home problems that required the integration of many related concepts (Appendix D). Problems with terminology were reduced through introduction of terms in their proper context or as inventions for things or processes after understanding and application. In short, the design of the laboratory exercises and related materials was a key factor in this study.

Construction of the Measuring Instruments

Subjective or intuitive evaluation of change and its concomitant effects can often lead to erroneous conclusions concerning the merits and subsequent ramifications of change. One must be constantly aware that personal biases of the investigator, if left uncontrolled, may subconciously influence the research decision. Thus, it behooves the researcher to take steps toward the utilization of instruments and techniques that guard against personal biases and increase the degree of objectivity of a study. Toward this end, this study utilized two objective measuring instruments, both constructed by the investigator. The first instrument consisted of a test designed to measure achievement in geology content. The second instrument utilized the semantic differential technique, described by Osgood,[64] to measure attitude.

Construction of the Achievement Test

Construction of the achievement test in geology content began in the 1968 Spring Semester. A 99 item, five-choice per item, objective examination (Appendix E) was constructed and administered to 283 students in the Introductory Geology Program. Student, faculty, and graduate assistant opinions concerning the quality of the items were solicited. On the

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[64]Osgood _et al._, _op. cit._

bases of their comments and student response, items were evaluated modified or discarded, and a second test was constructed for further modification. That second test, consisting of old, modified and new items, was constructed in the 1968 Fall Semester. A copy was distributed to faculty and graduate assistants for their opinions concerning accuracy of answers, wording, appropriateness, content coverage and general quality of the items. Seven tests were returned with written and oral comments. The test was administered to 516 students enrolled in the Introductory Geology Program at the close of the 1968 Fall Semester. The students' I.B.M. answer sheets were later submitted to the Merrick Computer Center at The University of Oklahoma for key punching and, subsequently, a point biserial item analysis.

The point biserial item analysis provided item data for construct validity of a subset of questions from the original 99 questions. Point biserial coefficients for each item were considered in conjunction with item difficulty and content validity in the selection of 60 questions. The intent was to select those items that had a high correlation with each individual's total test score, a range of difficulty that would provide gradation from easy to difficult, and contributed to the content validity of the 60-question subset. The result was that good construct validity was obtained as indicated by the t-values for each item coefficient, all t-values were well beyond the .001 level. Data in Table 3-3 indicated that the item difficulty ranged from .92 to .27 with an average difficulty of .55. Inspection of the content of each question confirmed an adequate range of content for good content validity.

TABLE 3-3

ITEM DIFFICULTY

Pi = Proportion Passing

Item	Pi	Item	Pi	Item	Pi
1	.40	21	.41	41	.50
2	.58	22	.42	42	.63
3	.76	23	.77	43	.46
4	.63	24	.51	44	.38
5	.69	25	.60	45	.50
6	.36	26	.64	46	.32
7	.57	27	.27	47	.61
8	.66	28	.32	48	.48
9	.46	29	.67	49	.61
10	.63	30	.72	50	.34
11	.42	31	.75	51	.30
12	.44	32	.64	52	.56
13	.62	33	.71	53	.60
14	.52	34	.43	54	.61
15	.86	35	.62	55	.39
16	.69	36	.62	56	.59
17	.59	37	.42	57	.51
18	.45	38	.92	58	.27
19	.59	39	.33	59	.76
20	.35	40	.82	60	.45
Range = .92-.27				Average = .55	

A Spearman-Brown estimate of the reliability of the test was performed with the I.B.M.-360 computer. A summary of the results (Table 3-4) indicated that the overall test parameters were as follows: reliability .89, mean 32.68, and standard deviation 9.64.

TABLE 3-4

ESTIMATE OF RELIABILITY

Odd-Even Means ($\bar{X}o$, $\bar{X}e$), Standard Deviations (σ_o, σ_e) and Reliability (r_{tt})

Odd Items	Even Items	Total	r_{tt}
$\bar{X}o$ = 16.71	$\bar{X}e$ = 15.97	32.68	
σ_o = 5.04	σ_e = 5.11	9.64*	.89

*Standard Deviation of total test

The entire 99-question test was utilized to gather the achievement data at the termination of the experiment that proceeded for the duration of the 1969 Spring Semester, but only the 60-question subset was actually scored. The rationale behind this procedure was that the parameters of the 60-question test were established as part of the original 99-question test, and one could not expect the parameters to remain the same once the subset was removed from the original whole because the influence of the remaining 39 questions would be removed. Rather than administer the 60-question test to a large population in order to establish the new parameters, the entire 99-questions were utilized to gather the final data. Normally, the administration of 99 questions and use of only 60 questions would constitute a waste of time or be prohibited by lack of time. Fortunately, this procedure saved time and work because the testing periods were long enough to allow all students ample time to complete all items.

Construction of the Semantic Differential

> "Of all the imps that inhabit the nervous system--that 'little black box' in psychological theorizing--the one we call 'meaning' is held by common consent to be most elusive. Yet, again by common consent among social scientists, this variable is one of the most important determinants of human behavior. It therefore behooves us to try, at least, to find some kind of objective index."[65]

Osgood's attempt "to find some kind of objective index" resulted in the development of a semantic differential test. The basic idea was that one has difficulty in assessing another's attitude toward a course, such as the geology laboratory class, by asking the individual how he feels about the course. Answers to such questions are generally in need of further analysis and complex interpretation, creating a high degree of subjectivity and at the same time producing a problem in terms of comparing answers from many individuals. The semantic differential test attempts to reduce the complexity by relying on objective responses to paired-adjectives that proved to produce high test validity and reliability.[66]

One page of the semantic differential test (Appendix F) utilized in this study is shown in Figure 3-2. Each page is headed with a concept[67] (in Figure 3-2 the concept is GEOLOGY LAB SHEETS) to be evaluated

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[65] Ibid., p. 10.

[66] Ibid., pp. 192-95.

[67] In keeping with Osgood, the word concept is used here in reference to a specific phase of a differentiated field. In this case, the geology laboratory course.

GEOLOGY LAB SHEETS

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

Figure 3-2. One Page of the Semantic Differential Showing Concept (GEOLOGY LAB SHEET) at Top of Page Followed by the Ten Scales of Paired-Adjectives.

according to the ten scales of polarized adjective-pairs. The concept varied with each page but the scales remained the same. Each student was provided with a set of simple instructions with examples at the beginning of the test (Figure 3-3). Students were instructed to mark one of the seven intervals between adjective-pairs. These intervals were later assigned numerical values from one to seven, with a value of one for the negative pole and a value of seven for the positive pole. Thus, students' responses were conveniently converted to a numerical value for analysis and computation.

Design of the ten scales required that attention be paid to choice of polarized adjective-pairs and sequence of arrangement. Four of the ten scales (constrained-free, usual-unusual, slow-fast, large-small) were distractors so their data were ignored during the final analysis and computation. The remaining six scales (meaningless-meaningful, interesting-boring, good-bad, positive-negative, disreputable-reputable, unsuccessful-successful) were selected for their "high loading" on evaluation factors[68] and relevance to the concepts to be evaluated. All of the scales were randomly assigned to a sequential position and polar orientation for the final test form.

Thirteen concepts were included in the test. Of these, seven were selected as representative of the phases of the geology laboratory course. They were as follows:

1. INTRODUCTORY LECTURE TO GEOLOGY LAB
2. GEOLOGY LAB SHEETS
3. STUDY OF MAPS

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[68]Osgood, et al., op. cit., pp. 50-55.

Instructions

The purpose of this study is to measure the meanings of certain things to various people by having them judge them against a series of descriptive scales. In taking this test, please make your judgments on the basis of what these things mean to you. On each page of this booklet you will find a different concept to be judged and beneath it a set of scales. You are to rate the concept on each of these scales in order.

Here is how you are to use these scales:

If you feel that the concept at the top of the page is very closely related to one end of the scale, you should place your check-mark as follows:

fair __X__:_____:_____:_____:_____:_____:_____ unfair

OR

fair _____:_____:_____:_____:_____:_____:__X__ unfair

If you feel that the concept is quite closely related to one or the other end of the scale (but not extremely), you should place your check-mark as follows:

strong _____:__X__:_____:_____:_____:_____:_____ weak

OR

strong _____:_____:_____:_____:_____:__X__:_____ weak

If the concept seems only slightly related to one side as opposed to the other side (but is not really neutral), then you should check as follows:

active _____:_____:__X__:_____:_____:_____:_____ passive

OR

active _____:_____:_____:_____:__X__:_____:_____ passive

The direction toward which you check, of course, depends upon which of the two ends of the scale seem most characteristic of the thing you're judging.

If you consider the concept to be neutral on the scale, both sides of the scale equally associated with the concept, or if the scale is completely irrelevant, unrelated to the concept, then you should place your check-mark in the middle space:

safe _____:_____:_____:__X__:_____:_____:_____ dangerous

IMPORTANT: (1) Place your check-marks in the middle of spaces, not on the boundaries:

THIS NOT THIS

_____:_____:_____:__X__:_____X_____:_____

(2) Be sure you check every scale for every concept--do not omit any.

(3) Never put more than one check-mark on a single scale.

Sometimes you may feel as though you've had the same item before on the test. This will not be the case, so do not look back and forth through the items. Do not try to remember how you checked similar items earlier in the test. Make each item a separate and independent judgment. Work at fairly high speed through this test. Do not worry or puzzle over individual items. It is your first impressions, the immediate "feelings" about the items, that we want. On the other hand, please do not be careless, because we want your true impressions.

Figure 3-3. Copy of Student Instructions for the Semantic Differential (After Osgood, 1957, pp. 83-84).

4. STUDY OF ROCKS AND MINERALS
5. LAB DEMONSTRATIONS, FILMS, SLIDES, PHOTOS AND MODELS
6. GEOLOGY LAB QUIZZES
7. GEOLOGY LAB ACTIVITIES

The rationale was that student response to each phase of the geology laboratory course could be combined to produce a more accurate total assessment of a student's attitude toward the laboratory than if he were asked to respond to the geology laboratory course as one concept. Two of the six concepts that were not used in the final assessment (THE UNIVERSITY OF OKLAHOMA, O. U. PROFESSORS) served as factors that were outside of the geology laboratory but still common to all students so that they acted as a check on the ability of the test to group responses on factors that were not varied or directly related to the experiment. The four remaining concepts (GEOLOGY LAB INSTRUCTOR; ME, AS A GEOLOGY LAB STUDENT; GEOLOGY LECTURE SECTION; DEGREE OF CORRELATION BETWEEN GEOLOGY LECTURE SECTION AND LAB) served as interesting fringe area concepts and distractors.

The implementation and completion of the preliminary procedures described in this chapter were paramount to formulation of this study. These procedures attempted to clarify those problems and procedures that related to improvement of the Introductory Geology Program and to the construction of evaluative instruments that were deployed to gather data as a basis for testing the inquiry and attitude hypotheses. Referring back to this chapter may be helpful when reading the following chapter concerning the design of the study.

CHAPTER IV

DESIGN OF THE STUDY

The preliminary procedures described in Chapter III were useful in framing the problem in terms of its component parts and in providing a basis for a more precise research design. The purpose of this chapter is to report on the specific structure and procedures of the study as outlined in the general model in Figure 4-1. The initial phase of the model, evaluation and formulation of the problem, was explained in Chapter I; therefore, it will not be repeated here.

The Research Hypothesis

The study was designed to test the following hypotheses.

When some students of introductory geology are taught by the experimental laboratory course and other students are taught by the traditional laboratory course, upon comparison of the results, the students taught by the experimental laboratory course will show a significantly:

(1) greater achievement in geology content as measured by an investigator-constructed achievement test on general physical geology.

(2) more favorable attitude toward their laboratory course as measured by an especially constructed test based on the semantic differential technique as described by Osgood.[69]

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[69]Charles E. Osgood, George J. Succi, and Percy H. Tannenbaum, The Measurement of Meaning (Urbana: University of Illinois Press, 1957).

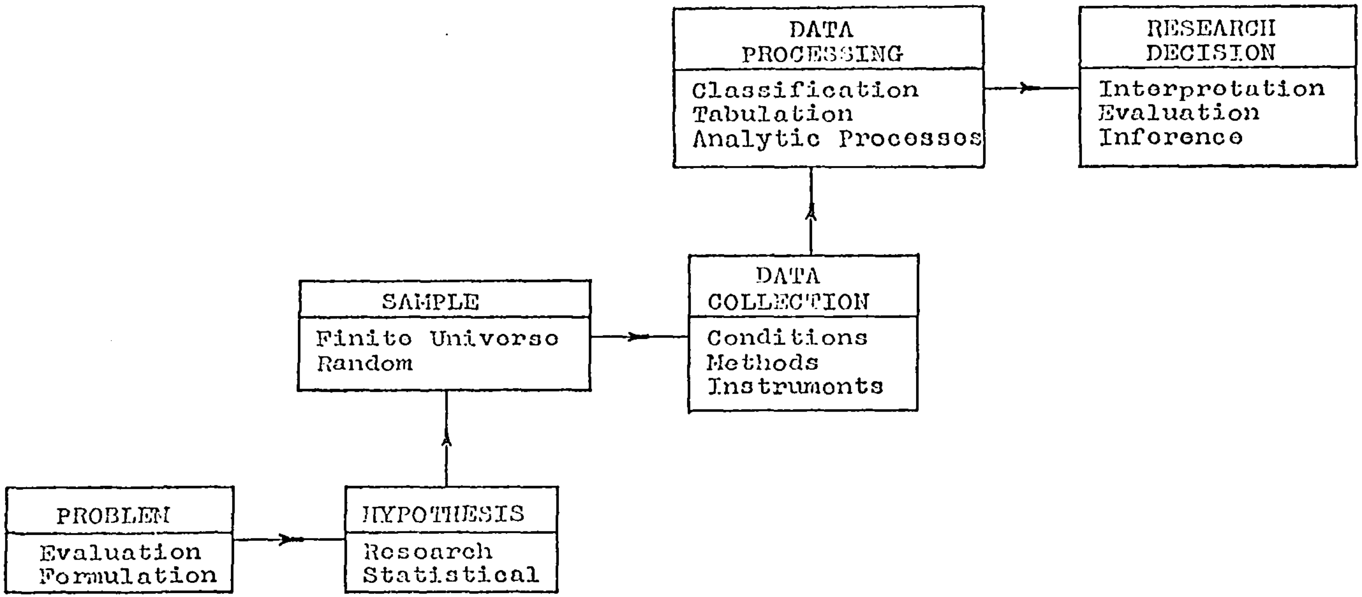

Figure 4-1. General Model of the Proposed Study (Modified after Hill and Kerber, Models, Methods, and Analytical Procedures in Education Research. Detroit: Wayne State University Press, 1967, p. 20).

Statistical Hypotheses

In order to facilitate the test of the research hypotheses, three statistical hypotheses were stated and tested in terms of the criteria, achievement in geology content, and student attitude toward their respective laboratory course.

(1) Students who are taught by the experimental course score significantly different than students who are taught by the traditional course.
Null form: Students taught by the experimental course do not score significantly different than students taught by the traditional course.
Symbolically, the two alternatives will appear as follows:

$$H_1: \ A_e \neq A_t$$

$$H_o: \ A_e = A_t$$

H_1 indicates the statistical alternative hypothesis; A_e indicates the mean score of students taught by the experimental course; and A_t indicates the mean score of the students taught by the traditional course. H_o indicates the "null" hypothesis.

(2) There is a significant difference between the students taught by instructor B_1 and those taught by instructor B_2, regardless of the course applied.
Null form: There is no significant difference between students taught by instructor B_1 and those taught by instructor B_2, regardless of the course applied.
Symbolically, the two alternatives appear as follows:

$$H_2: \ B_1 \neq B_2$$

$$H_o: \ B_1 = B_2$$

(3) There is a significant interaction between instructor and course applied.
Null form: There is no significant interaction between instructor and course applied.
Symbolically, the two alternatives appear as follows:

$$H_3: \ A_eB_1 \neq A_tB_1$$

$$A_eB_2 \neq A_tB_2$$

$$H_o: \ A_eB_1 = A_tB_1$$

$$A_eB_2 = A_tB_2$$

The "null" hypotheses were tested at the .10 significance level. Computed sample data in terms of achievement and attitude were compared, and assuming that the hypothesis was true, the probability of getting a finding as deviant from the expectancy as the one obtained was determined. If the probability of a finding as deviant as the one obtained was greater than the .10 significance level, the hypothesis could not be rejected. If the probability of a finding as deviant as the one obtained was less than .10 significance level, the hypothesis was rejected and its alternative hypothesis was accepted.

Selection of a .10 level of significance as a basis for testing the null hypothesis was based on consideration of the two types of error, type I and type II (Table 4-1), and their consequences.

TABLE 4-1

TWO TYPES OF ERRORS[70]

(H_O = null hypothesis)

	DECISION	
	Reject H_O	Accept H_O
H_O True	Type I Error	Correct
H_O False	Correct	Type II Error

A type I error is made if the null hypothesis being tested is actually true, but the test of significance results in rejection of the

[70]After J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill Book Company, 1965), p. 206.

hypothesis. If the hypothesis being tested is actually false, but the test of significance results in the acceptance of the hypothesis, then an error of type II has been made. An overly cautious investigator would tend to avoid a type I error by selecting a small value for the level of significance (high level of confidence). He may select a .05 level of significance and take the chance of being wrong five times out of a hundred, or he may select an even lower value, say .01, and take the chance of being wrong only one time out of a hundred. It is readily seen that the smaller the value of the level of significance, the less chance there is of making a type I error. The problem is that as the value of the level of significance is reduced, the chances of making a type II error increase.

The dilemma can be resolved if one gives consideration to the consequence of each type of error. Guilford states that:

> Some kind of balance is called for. Considerations external to the data themselves should be noted and given weight. There may be serious theoretical or practical reasons why it would be costly to make one kind of error or the other. Thus, this question ultimately cannot be decided on purely statistical grounds.[71]

If a small value for the level of significance is selected, the possibility of making a type I error is also small. That is, the hypothesis will seldom be rejected, and when the hypothesis is true a correct decision will usually be made. When the hypothesis is false, however, chances of making a type II error will be high. In terms of the hypothesis in this study, a type II error means that there is actually a difference due to treatments, but the investigator is led to believe that

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[71] Ibid., p. 207.

there is no difference. Thus, the investigator will lose an opportunity to promote the acceptance of an educational approach that, if implemented, would benefit numerous students. This factor is of paramount importance when one recognizes that in decisions of an educational nature the welfare of the students is the prime consideration.

On the other hand, if a large value for the level of significance is selected, the possibility of making a type I error is increased, chances of making a type II error are decreased, and when the hypothesis is false a correct decision will usually be made. A type I error means that the investigator will be led to conclude that there is a difference due to treatments when in fact there is no difference. Thus, he will be encouraged to adopt the experimental course under the false impression that it is superior to the traditional course. The results of such a decision would be of no particular consequences because there would be no difference between the approaches and students would not suffer, as they would be expected to achieve equally well with either approach. The only drawbacks would be the inconvenience of preparing instructors for the new approach, and a slight increase in costs due to the added materials.[72]

In sum, a type I error would not be detrimental to the students, and a type II error would prevent the students from taking advantage of an approach that would be superior to the traditional approach and thereby deprive numerous students of an opportunity to benefit from

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[72]It is estimated that initial cost of materials for three laboratories would be about $920. These materials would be used by an average of 1400 students per year at The University of Oklahoma with an estimated cost of replacement for expendable items at less than $100 per year.

increased achievement and/or favorable attitude. A small value, such as .05 or .01, for the level of significance would favor a type II error and result in a loss to the students. A large value, such as .20 or greater, for the level of significance would favor a type I error, reduce the chance of a type II error, and not result in any harmful effects for the students. Thus, the selection of the .10 level of significance represents a compromise that tends to favor the best interests of the students while maintaining a fair to good level of confidence.

Population and Sample

The population under study was composed of students enrolled in the Introductory Geology Program at The University of Oklahoma. A survey of 358 students indicated that the population consisted of 53 percent males and 47 percent females, of whom 35 percent were freshmen, 33 percent were sophomores, 20 percent were juniors and 12 percent consisted of seniors, unclassified or graduate students. They represented 23 major fields of study with the highest percentage (5.6%) claiming a major in Pre-medicine, and Psychology (see Table 3-2).

The sampling procedure for the study was based on the random distribution of students through student-scheduling, to 27 Introductory Geology laboratory classes. All students were free to select one of the 27 laboratory classes which were scheduled Monday through Friday with as many as three laboratory classes scheduled for the same time. Selection of a laboratory class was determined by the student's major, availability of the laboratory classes and other courses and personal preference. Thus, the great number of variables that influenced the schedule of each student and the lack of criteria for acceptance into any laboratory class justified the assumption of a random sample.

Basic Research Design and Experimental Procedures

The basic research design (Figure 4-2) for the study was a randomized, 2 x 2 factorial design[73] that utilized four groups and two instructors; each instructor conducted a control group (traditional course) and an experimental group. The independent variables were methods and materials, and instructors; dependent variables measured were achievement in geology content, and student attitude.

	Methods & Materials	
	TRADITIONAL A_t	EXPERIMENTAL A_e
INSTRUCTOR B_1	A_t B_1	A_e B_1
	Dependent Variables	
	Achievement & Attitude	
INSTRUCTOR B_2	A_t B_2	A_e B_2

Figure 4-2. Basic Research Design. A Randomized, 2 x 2 Factorial Analysis.

Students were randomly scheduled to four laboratory classes which in turn were randomly assigned to two instructors, two classes to each instructor. Thus, randomization permitted the investigator to assume that the control groups and the experimental groups were the same in all respects except in terms of method and materials. The control groups were taught by the lecture-participation method as was commonly utilized

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[73]Fred N. Kerlinger, Foundations of Behavioral Research (New York: Holt, Rinehart and Winston, Inc., 1964), pp. 213-41.

in the traditional laboratory course--an approach that relied heavily on lecture presentation, maps, rocks, and minerals, respectively, with a little attention to audio-visual aids. The experimental groups were taught by a structured-inquiry approach based on redesigned laboratory exercises that incorporated new materials, models and audio-visual aids as delineated in chapter three. Thus, the independent variables were instructors, and methods and materials, and the dependent variables were achievement in geology content, and attitude of the students toward their respective laboratory class.

The above procedure of combining method and materials to form one variable was consistent with the concept of maximizing the variance of the variable as delineated by Kerlinger.[74] That is, the investigator had to take steps to insure that the treatment of the two groups was as polarized as possible. Stephens[75] stated that research results indicated that many investigators, in their zeal to control, overcontrolled the experiment and thereby "choked" the effect of the independent variable. Restriction of the independent variable to method would reduce the variance between the two approaches. As stated in Chapter I under Limitations of the Study, the combining of method and materials into one variable precluded the detection of a separate effect for each.

An advantage of this type of research design was that it did not require a pre-test, so the risk of sensitizing the students to the

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[74] Ibid., p. 283.

[75] J. M. Stephens, The Process of Schooling: A Psychological Examination (New York: Holt, Rinehart and Winston, Inc., 1967), p. 83.

achievement test in geology content was eliminated. Another advantage was the "check" provided by the impartial instructor and his control and experimental groups. This essentially constituted an experiment that was parallel to the experiment conducted by the investigator, and as such it tended to provided two controlling factors. The first factor was that it helped to sensitize the investigator toward the inherent biases that he had for his coveted hypothesis.[76] It was not a question of honesty, it was a trait of human behavior of which an investigator had to be aware.[77] The use of another person to perform a parallel experiment served as a reminder to the investigator that while it was desirable to maximize the variance between groups, he had to attempt to prevent his biases from acting as an uncontrolled variable. The second factor was that the data from the two parallel experiments were manipulated and combined in such a way that the affect of uncontrolled biases tended to be ameliorated and the results were usually conservative.[78]

The disadvantage of having an impartial instructor, in addition to increasing the variables by one, was that he may have been "too impartial" to the point that details were not attended to in a conscientious manner. This could happen if the impartial instructor saw no harm in telling the students in both groups the "answers" rather than allowing the students

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[76]T. C. Chamberlin, "The Method of Multiple Working Hypotheses," Science (May 7, 1965), 754-59.

[77]For many examples of how an investigator's expectations influence research results, see Robert Rosenthal and Lenore Jacobson, Pygmalion in the Classroom (New York: Holt, Rinehart and Winston, Inc., 1968), pp. 182.

[78]Edwards, op. cit., chapter 12.

in the experimental group to gain confidence in finding out for themselves. Since the outcomes of the experiment were of little or no consequences toward his welfare, the impartial instructor may have allowed his biases to go "uncontrolled" more so than the investigator. This would have resulted in the two approaches resembling each other more than intended, with a loss in variance between the control and experimental groups.

The experiment continued for the entire 1969 spring semester and terminated with the deployment of the two evaluative instruments; an achievement test in the content of geology, and a semantic differential test designed to measure attitude of the students toward their respective geology laboratory class. The data collected, processed and interpreted are discussed in the following chapter.

CHAPTER V

DATA COLLECTED, PROCESSED AND INTERPRETED

The two evaluative instruments--test of content achievement in geology, and a semantic differential test--yielded data concerning the students' understanding of content in geology and their attitude toward their geology laboratory class, respectively. The aim of this chapter is to view the data collected, describe the analytical procedures used to process the data, and discuss possible interpretations of the data and calculated results. The first part of the chapter will focus on the analysis and interpretation of the data on student achievement in geology content, while the last part of the chapter will concentrate on assessing student attitude.

Achievement in Geology

Table 5-1 lists the achievement scores in geology for the four groups of students involved in the experiment. Means and standard deviations for each group are located at the bottom of the table, and also in Figure 5-1 for a better perspective of how they relate to the research design.

Both Table 5-1 and Figure 5-1 indicated that the means varied between groups, but without further calculations one could not ascertain the degree of significance between means.

TABLE 5-1

ACHIEVEMENT SCORES IN GEOLOGY

Methods (A_e, A_t) and Instructors (B_1, B_2)

Methods & Materials A_t		Methods and Materials A_e	
1	2	3	4
A_tB_1	A_tB_2	A_eB_1	A_eB_2
55	50	55	51
53	47	51	48
52	46	50	47
47	44	48	46
46	40	45	46
43	40	45	43
43	37	42	42
43	37	42	42
41	34	41	40
41	34	40	40
37	33	40	39
36	33	37	39
36	32	34	38
35	31	34	37
35	30	34	37
29	30	30	36
27	26	27	34
26	25	20	33
26	20	--	33
23	--	--	33
22	--	--	30
21	--	--	27
--	--	--	26
--	--	--	17
$\bar{x}$=37.14	$\bar{x}$=35.21	$\bar{x}$=39.72	$\bar{x}$=37.67
σ=10.19	σ= 7.68	σ= 8.67	σ= 7.66

	Methods & Materials	
	Traditional A_t	Experimental A_e
Instructor B_1	1 A_tB_1 $\bar{x} = 37.14$ $\sigma = 10.19$	3 A_eB_1 $\bar{x} = 39.72$ $\sigma = 8.67$
	Dependent Variable Achievement in Geology	
Instructor B_2	$\bar{x} = 35.21$ $\sigma = 7.68$ A_tB_2 2	$\bar{x} = 37.67$ $\sigma = 7.66$ A_eB_2 4

Figure 5-1. Basic Research Design with Means and Standard Deviations of Data Obtained from an Achievement Test in Geology.

In order to make a statistical comparison between the groups and determine the level of significance, an analysis of variance on the data of Table 5-1 was conducted and F-ratios were computed.[79] A summary of the analysis of variance of achievement scores in geology is given in Table 5-2.

Although the means for the two experimental groups were higher than the means for the traditional groups, inspection of the results in Table 5-2 indicated that the differences between the groups were not

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[79]Allen L. Edwards, Experimental Design in Psychological Research (New York: Holt, Rinehart and Winston, Inc., 1950), pp. 208-33.

TABLE 5-2

ANALYSIS OF VARIANCE OF ACHIEVEMENT SCORES IN GEOLOGY

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	F-ratio $F_{.10} \geq 2.77$
Methods & Materials	110.11	1	110.11	1.10
Instructor	61.20	1	61.20	0.61
Interaction	20.07	1	20.07	0.20
Within Groups	8100.69	79	100.26	
Total	8292.07	82		

significant at the .10 level. Effects of methods and materials, instructors, and interactions between methods and materials and instructors failed to produce any significant (.10) differences in students' achievement scores in geology. On the basis of these results, this investigator recognized that the null hypotheses as originally stated in Chapter 4 could not be rejected and he concluded that:

1. Students taught by the experimental course did not score significantly (.10) different on content achievement than students taught by the traditional course.
2. There was no significant (.10) difference on content achievement between students taught by instructor B_1 and those taught by instructor B_2, regardless of the course applied.
3. There was no significant (.10) interaction between instructor and course applied.

There were many possible explanations as to why the results failed to show a significant difference. Of prime consideration was the possibility that a significant difference did indeed exist; however, the evaluative instrument was insensitive and therefore failed to detect the difference. This possibility was supported by the understanding that it was very difficult to measure the higher intellectual processes that one hoped to stimulate by way of inquiry.[80] Paper and pencil type tests were best suited to measurement of knowledge of specifics, but tended to be questionable when attempting to detect one's ability to analyze, synthesize, translate and evaluate.

A second possibility was that the evaluative instrument was sensitive to differences, but in reality there were no differences to be detected; the two treatments were too much alike. They resembled each other more than they differed. Such a possibility could have been due to the instructor's ambivalence between their desire to maximize the variance between treatments on the one hand, and their sensitivity toward fairness and personal biases on the other hand. Failure to maximize the variance between treatments could have also resulted from the instructors' failure to adequately conceptualize the difference between treatments, so they viewed both approaches as means to mere transmission of facts and terminology. That possibility could have easily happened in the case of an instructor who has had no special education in inquiry techniques and lacked an intuitive understanding of inquiry.

Attitude Toward the Geology Laboratory Class

Attitude scores yielded by the utilization of the semantic differential test are listed in Table 5-3. Means and standard deviations

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[80]Benjamin S. Bloom, ed., Taxonomy of Educational Objectives (New York: Longsman, Green and Company, 1956).

TABLE 5-3

ATTITUDE SCORES FROM THE SEMANTIC DIFFERENTIAL TEST

Methods (A_e, A_t) and Instructors (B_1, B_2)

Methods & Materials A_t		Methods and Materials A_e	
1	2	3	4
A_tB_1	A_tB_2	A_eB_1	A_eB_2
279	264	281	274
259	257	279	249
247	254	277	245
229	238	256	234
226	237	246	232
215	232	232	231
214	230	226	225
211	219	226	222
206	217	223	218
203	206	220	216
187	206	220	216
186	200	220	215
181	196	215	214
180	193	214	213
178	193	210	210
170	168	208	201
166	165	180	198
159	163	159	196
157	154	---	183
133	---	---	178
115	---	---	175
63	---	---	166
---	---	---	161
---	---	---	144
$\bar{x}$=188.91	$\bar{x}$=210.11	$\bar{x}$=227.33	$\bar{x}$=209.00
σ= 46.62	σ= 32.14	σ= 31.01	σ= 29.56

are recorded at the bottom of each group of raw scores. Figure 5-2 displays the partitioning of the means and standard deviations according to the cells of the basic research design.[81]

	Methods & Materials: Traditional A_t	Methods & Materials: Experimental A_e
Instructor B_1	1 A_tB_1 $\bar{x}$ = 188.91 σ = 46.62	3 A_eB_1 $\bar{x}$ = 227.33 σ = 31.01
	Dependent Variable Attitude	
Instructor B_2	$\bar{x}$ = 210.11 σ = 32.14 A_tB_2 2	$\bar{x}$ = 209.00 σ = 29.56 A_eB_2 4

Figure 5-2. Basic Research Design with Means and Standard Deviations of Scores on the Semantic Differential.

Statistical comparisons between the groups were conducted by way of analysis of variances in order to ascertain the presence of

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[81]It was noted in Table 5-3 and Figure 5-2 that the standard deviation of the scores in group 1 was 46.62 compared with the standard deviations of 32.14, 31.01, and 29.56 for the scores in the other groups. It was felt that the extremely deviant score of 63 for one student in group 1 was mainly responsible for this, so as a check, the score was cast out, and the mean and standard deviation computed to 194.90 and 36.13, respectively. This resulted in a lower F-values, but since they remained significant at the .10 level, no further attention was given to the effect.

significant differences in student attitude toward their geology laboratory class. Table 5-4 displays the results. Two significant F-values were obtained above the .10 level of confidence. One favored the experimental approach at the .025 level while the other indicated a significant interaction also at the .025 level between instructor, and methods and materials. There was no significant difference between instructors in terms of their overall effectiveness with both of their classes.

TABLE 5-4

ANALYSIS OF VARIANCE OF ATTITUDE SCORES

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Square	F-ratio $F_{.10} \geq 2.77$
Method & Materials	7059.82	1	7059.82	5.43*
Instructor	224.07	1	224.07	0.17
Interaction	7569.72	1	7569.72	5.82*
Within Groups	102707.61	79	1300.00	
Total	205415.22	82		

*Significant at the .025 level.

On the basis of these results, this investigator concludes that two of the three original null hypotheses had to be rejected and their alternative forms accepted. Thus, it followed that:

1. Students who were taught by the experimental course scored significantly higher in terms of favorable attitude toward their geology laboratory course than students who were taught by the traditional course.

2. There was no significant difference in terms of attitude between the students taught by instructor B_1 and those taught by instructor B_2.

3. There was a significant interaction between instructor and course applied. Instructor B_1 was more successful with the experimental course.

The above results indicated that the method and materials of the experimental course were significantly (.025) more effective in promoting favorable student attitude toward their geology laboratory course than was the traditional course. This meant that there were 2.5 chances out of a hundred that such a difference in attitude between students in the two courses could occur by chance alone. Since the two courses differed only in method and materials--there was no significant difference in terms of attitude and content achievement between the students taught by instructors B_1 and B_2--the significant difference in attitude was attributed to the difference in method and materials of the two approaches. Evidently a structured-inquiry approach was successfully implemented to promote favorable attitude in a geology laboratory course.

In view of the above finding one had to refer to Table 3-1 which indicated that 1.7 percent of all students surveyed claimed a geology major, and refer to page 38 where talks with geology professors indicated that at least 95 percent of all students enrolled in introductory geology were non-majors, in order that the real significance of the finding in terms of outcomes of instruction in geology be perceived. A favorable attitude toward the structured-inquiry approach reflected a favorable attitude toward the characteristics of such an approach (see chapter 2);

viz., the student as an active inquirer; science as a process involving higher intellectual powers, rather than the mere storage and recall of factual knowledge; the teacher as a guide, rather than a "teller" or transmitter of factual knowledge; and the use of a diverse range of materials. If one recognized the value of such favorable student attitudes, then it became increasingly difficult to justify a geology course that emphasized content and failed to promote favorable attitudes toward geology and science, especially for the non-major. What was really gained by a content oriented approach if students developed attitudes toward geology and science which were unfavorable. One student from the traditional course summarized those unfavorable attitudes succinctly when he remarked to this investigator, "I received a grade of A in both the lecture and the laboratory, but I have a strong desire to burn my laboratory manual."

Another finding, that there was a significant interaction between instructor B_1 and course applied, indicated that instructor B_1 was more successful with the experimental approach. This effect was accounted for by considering the educational background and experiences of the two instructors. Instructor B_1 was educated as a science teacher and had acquired six years of experience in teaching science in secondary schools. He also had four years of involvement with inquiry techniques through graduate study in science education. In addition, he had three years of classroom and field experience as a graduate assistant and instructor in earth science. Instructor B_2 was educated as a geologist and he had taught the geology laboratory course for one semester prior to taking part in the study. Thus, it was concluded that past experience with the inquiry approach was conducive to increased effectiveness as an instructor when employing the structured-inquiry approach. On the other hand, it was also concluded that experience as an instructor produced no significant differences in content achievement, and a graduate assistant with little or no teaching experience and an experienced instructor were both equally effective in transmitting factual knowledge.

In summary, the results based on both student achievement and student attitude indicated that the methods and materials produced no significant difference in student content achievement, but they did produce a significant difference (.025) in student attitude. When all of the geology achievement scores for all students taught by instructor B_1 were combined and compared with all of the geology achievement scores of students taught by instructor B_2, there was no significant difference between the groups; thus, both instructors were equally successful in terms of promoting achievement in geology content. When the same kind of comparison was made on the basis of attitude scores, no significant differences were detected so both instructors were equally successful in promoting favorable attitudes. But when the effectiveness of each instructor with each of the two approaches was assessed, instructor B_1 was significantly (.025) more successful with the experimental course in terms of favorable student attitude.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

This study represented an attempt to assess the relative effectiveness of a structured-inquiry geology laboratory course as compared to the traditional geology laboratory course, and to design an introductory geology laboratory course that would overcome the problems of the traditional course without a reduction in student achievement or favorable student attitude. Preliminary procedures extended throughout the 1968 calendar year and the experiment was conducted during the 1969 Spring Semester. Preliminary procedures consisted of:

1. Survey of faculty and graduate assistants concerning goals for the Introductory Geology Program.
2. Survey of 258 students' academic background.
3. Design of twelve laboratory exercises with related materials.
4. Design and construction of an achievement test, administration of the test to 283 students, followed by modification and administration to 516 students and subsequently, calculation of reliability and validity.
5. Design and construction of a semantic differential test.
6. Two semesters of exploratory work in the geology laboratory classes as an instructor.

The basic research design consisted of a 2 x 2 factorial analysis. Two instructors and four groups of introductory geology students were randomly assigned to four cells. Each instructor was responsible for two classes, an experimental class and a traditional class. The experimental class received a wide range of activities and materials and were encouraged to work with a minimum amount of direction from the instructor, whereas the traditional class continued to rely on lecture presentations followed by instructor-directed student activities that were restricted to primarily rocks, minerals, and maps, but mostly maps.

Upon completion of the treatment, data concerning student achievement in geology and student attitude toward their respective class were collected by way of an achievement test in geology and a semantic differential test for attitude. The data gather were processed by an analysis of variance technique, and F-values were computed so the groups could be compared for statistically significant differences at the .10 level.

Although the means of the content achievement scores in geology were slightly higher for the experimental groups, F-values indicated that they were not significant (.10). Neither of the independent variables, instructors or methods and materials, produced significant differences in student content achievement scores in geology. No significant interaction was found between method and instructor. This meant that both instructors were equally effective with either method in promoting student content achievement in geology.

F-values based on the analysis of variance of attitude scores indicated a significant (.025) difference in favor of the experimental approach, and a significant (.025) interaction between instructor and method. Students in the experimental groups showed a significantly more favorable attitude toward their geology laboratory class than students who were in the traditional geology laboratory class. The instructor with the greatest amount of experience in teaching and acquaintance with inquiry techniques was significantly more successful with the experimental course than he was with the traditional course.

In addition to testing the hypotheses relating to the relative effectiveness of the structured-inquiry approach as compared to the traditional approach, this investigator was interested in answering the question: Is it possible to design and implement an introductory geology laboratory course that will overcome the problems of the traditional course (see pages 5 and 55) without a reduction in student achievement or favorable student attitude? The experimental evidence of this study justified an affirmative reply to the question because the experimental approach produced slight, non-significant increases in student achievement while increasing student attitude significantly. This latter finding was very encouraging when one considered that 95 percent of the students were non-majors and it was desirable that they develop favorable attitudes toward geology and science in general. It also confirmed a belief held by this investigator, viz., that geology was an inherently interesting discipline which held a natural appeal for students when they were not overwhelmed by a flood of factual knowledge steeped in trivia. A geology course that appealed to the non-major did not mean a reduction in "standards," content achievement was maintained while increasing favorable attitude toward geology.

This investigator believes that the effectiveness of future studies on this topic can be enhanced by the utilization of Flanders-type[82] techniques for observing and categorizing teacher-student interaction in the classroom. Such techniques may be used to select instructors that have equal ability to interact with students under traditional and experimental conditions. The instructors may then be assigned to the four cells of the 2 x 2 factorial design with a greater possibility of maximizing the variance since it would be possible to select instructors who can conceptualize the nature of both the experimental and the traditional approach. It is hypothesized that such procedures will result in greater significant differences between approaches.

Another suggestion for future studies in this area is the use of new techniques to detect higher levels of intellectual thought as stimulated by inquiry-type approaches. Unfortunately, such levels of thought are difficult to detect by way of objective pencil and paper tests. It is recommended that future research in the geology laboratory course attempt to detect the higher levels of thought by utilization of an independent judge and Piagetian type tasks as described in Inhelder and Piaget.[83] Modifications of the Piagetian type tasks to demonstrate one's understanding in geology may be more effective than pencil and paper type tests, and the use of an outside judge will free the investigator from contaminating the results with personal biases.

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[82] Ned A. Flanders, Interaction analysis in the classroom: A Manual for Observers (Ann Arbor: University of Michigan Press, 1964).

[83] Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking: From Childhood to Adolescence, trans. by Anne Parsons and Stanley Milgram (USA: Basic Books, Inc., 1958), pp. 356.

An intuitive outcome of this study that warrants further investigation is the belief that some students may be more successful with the alternative approach, i.e., some students in the traditional course may have performed better in the experimental course, whereas some students in the experimental course may have performed better in the traditional course. This is based on the observation that the student who is self-directed appears to thrive in an inquiry-type atmosphere, while the student who needs teacher-directed activities appears to do well with the traditional course. An interesting study could be made if accurate descriptions of alternative approaches were publicized and students were permitted to select an alternative. One wonders how the achievement and attitude of students in such courses would compare with students who have been randomly assigned to the experimental course and the traditional course.

The School of Geology and Geophysics at The University of Oklahoma, as well as disciplines in other departments and at other institutions, are strongly urged to consider the merits of such a multiple-alternatives approach. Such a program would also provide alternatives for the professors by allowing them a wide range of latitude in designing and publicizing their own course. Instead of forcing the professor to adjust to a course, he will be responsible for developing his own and selecting his methods and materials. A program of this type would have the greatest chance for success in courses such as General Geology where the enrollment is 500 or more and many professors and instructors are involved. There is no educational justification for requiring all students to take the same course. If each professor were charged with developing his course in competition with several other professors, the increase in interest and quality would do much to overcome the one-course, one-book stagnation that is thrust upon the professors under the present system.

In conjunction with the above recommendation, it would be unwise for the School of Geology and Geophysics at The University of Oklahoma to adopt the experimental course as the course for all students, despite its success in promoting favorable student attitude. The goal should not be to provide one course for every student, but to provide every student with a choice.

In addition to the above recommendations, the following specific suggestions are made in reference to the Introductory Geology Laboratory course and the related lecture sections.

1. Every professor and instructor should inform his students prior to or early in the semester concerning the objectives of the course and bases for evaluation of student achievement. This could be accomplished by the distribution of a detailed course description indicating the instructor's approach to the course and the major concepts and understandings that will be stressed. It should be possible for a "hard core" of major concepts to be developed by general consensus of the faculty, with allowance for the addition of other concepts by the individual instructor. Such an approach would help to have the instructor examine his thinking concerning the course, and the student will be helped to discern between the big ideas and the trivia. In this way the instructor, and students will be cooperating in working toward common goals rather than assuming the role of adversaries.

2. Weekly seminars should be conducted for laboratory instructors so that they may be introduced to the alternative approaches to teaching and be made more sensitive toward their students. This will help them adjust to a new teaching situation and will be especially useful for those who go on to a teaching position after graduation. Perhaps the seminar could be conducted in cooperation with Science Education as a required course for all graduate assistants.
3. Laboratory activities should be designed by faculty and graduate assistants. This is desirable because it allows them to incorporate factors from the local and regional geology. But more important, it provides for constant examination and redesign of each activity so that what appears to be effective is retained, while the ineffective is discarded or modified. Such a procedure would avoid the drawbacks of a commercially produced laboratory series which usually contain both positive and negative factors and the exchange of one series for another only results in a different set of negative factors.
4. The laboratory course should either be correlated with the lecture or it should be isolated. It now functions on the premise that it is correlated with the laboratory but in practice there is very little correlation between the two; consequently, problems are created for both the laboratory student and the instructor. Consideration should be given to a laboratory course that is an integral

part of the lecture section and correlation is maintained by the lecture professor. Another alternative would be to design a laboratory course that operated in relative isolation from the lecture and provided students with an opportunity to select their activities from several possibilities.

5. As mentioned earlier, each lecture section should be viewed as a separate course, designed and implemented to capitalize on the full creative capacity of the professor and students.

6. Field trips should be taken early in the semester in order to establish a frame-of-reference for subsequent classroom work. Students should be encouraged to take field notes and photographs which will aid later classroom discussion and explanation.

7. The Geology I storerooms should be renovated to accommodate equipment other than the traditional rocks, minerals and maps.

8. A faculty member, preferably one who is interested in both education and earth science, should be <u>the</u> geology resource person in the Department. This individual will report to the faculty concerning learning aids, problems, trends and alternatives to education in earth science. He should be a person to whom all faculty members can rely on for assistance in problems of an educational nature.

9. Consideration should be given to an introductory course

or courses that are geared to the non-major. At least 95 percent of the students enrolled in the introductory course will not become geology majors, but the present program continues to be oriented toward the geology major. Members of the community of geologists are missing a golden opportunity to provide students with an understanding of how geology is related to our contemporary society and what contributions the geologist has to make toward the support and improvement of our society.

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APPENDICES

APPENDIX A

GOALS FOR GEOLOGY I

Dear Faculty Member:

The following items represent an attempt to list the possible goals for Geology I. You are asked to indicate your reaction by circling the appropriate word (approve, disapprove, or undecided). Regardless of how you respond, please feel free to make additional comments in the area provided below each goal. For each one approved, please rate it on a 1 (lowest) to 5 (highest) scale.

Thank you for your interest and cooperation in this endeavor.

Frederick P. DeLuca
Box 218 A

1. To help the student gain an understanding of the history of the earth.

Approve
Disapprove
Undecided

2. To help the student understand the work of the geologist.

Approve
Disapprove
Undecided

3. To help the student develop an understanding of the evolution of thought that influenced geology.

Approve
Disapprove
Undecided

4. To provide the student with an opportunity to grow intellectually.

Approve
Disapprove
Undecided

5. To help the student understand the unsolved problems in geology and their concomitant inherent difficulties.

Approve
Disapprove
Undecided

6. To give the student who takes no further courses in geology an opportunity to gain an understanding of his earthly environment and its limitations.

Approve
Disapprove
Undecided

7. To help the student gain as much factual knowledge and terminology in geology as is possible during the relatively short period of one semester.

Approve
Disapprove
Undecided

8. To encourage the bright student to pursue the field of geology as a career.

Approve
Disapprove
Undecided

9. To help the student gain an understanding of the earth's natural resources, their uses and their limited amounts.

Approve
Disapprove
Undecided

10. To prepare the student for more advanced study in geology.

Approve
Disapprove
Undecided

11. To meet the needs of the liberal arts student.

Approve
Disapprove
Undecided

12. To help the student understand the relationships between geology and man.

Approve
Disapprove
Undecided

13. To help the university screen out low ability students.

Approve
Disapprove
Undecided

14. To help the student grow in the knowledge and use of scientific procedures in problem solving.

Approve
Disapprove
Undecided

15. To provide the student with an opportunity to study earth science; i.e., geology and related fields--climatology, soils, meteorology, oceanography and astronomy.

Approve
Disapprove
Undecided

16. To guide the student in the formulation of reasonable generalizations from specific data of an experiment.

Approve
Disapprove
Undecided

17. To help students grasp an understanding of the "structure" of geology; i.e., the broad concepts and relationships that thread through geology and related fields as supported by facts.

Approve
Disapprove
Undecided

18. To help the student gain an understanding of the contributions made by the great pioneers in geology.

Approve
Disapprove
Undecided

19. To provide the student with the opportunity to develop problem-solving skills through the process of inquiry.

Approve
Disapprove
Undecided

20. To help the student understand the environmental problems created by our society, and encourage him to take an active interest in their solution.

Approve
Disapprove
Undecided

21. To help the liberal arts student gain a better understanding of science so that he may better close the communications gap between the arts and the sciences.

Approve
Disapprove
Undecided.

22. To help the student understand the forces and processes that shape the crust of the earth.

Approve
Disapprove
Undecided

23. To help the student see geology as a human activity viewed in a historical and philosophical perspective.

Approve
Disapprove
Undecided

24. To help the student develop skill in the rudimentary techniques utilized in geology; i.e., rock and mineral identification, and reading of topographic and geologic maps.

Approve
Disapprove
Undecided

25. To help the student meet his science requirement for his degree program.

Approve
Disapprove
Undecided

26. To provide the student with an opportunity to utilize quantitative data (chemistry, physics and math) in the solution of elementary problems in geology.

Approve
Disapprove
Undecided

Please add any additional suggestions or comments concerning the overall area of goals.

APPENDIX B

QUESTIONNAIRE *

INTRODUCTION

During the past few years there has been an increased emphasis placed on science teaching. High school and college curriculum have undergone many changes. This is particularly true of the teaching of the Earth Sciences. New Earth Science programs have been started, or are being planned, by many high schools. In order for colleges to keep pace with these new programs, periodic surveys must be made. This questionnaire is designed to give us a better "picture" of the typical Earth Science student--his needs both now and in the future.

(All answers will be kept confidential)

Name (optional) ________________________________ Age________

Male____________ Female________ Married________ Single__________

General

If you are not planning on majoring in Geology, indicate why no by checking any of the following which may apply:

Not interested in occupational or professional career ________

Not enough challenge in Geology ________

Not enough job opportunity in Geology ________

Enthusiasm dulled by this or previous Geology ________

Not interested in science ________

Other____

If you are planning on majoring in Geology, we would appreciate a brief statement indicating how you became interested in Geology as a career

____

____

____

(*Modified after Edward Stoever, Jr., 1964.)

Is knowledge of geology useful to the average citizen? Yes_____ No____

Why are you taking Geology I? (Check one or more)

To meet my science requirement _______

I thought it would be interesting _______

It is generally considered to be an easy course _______

Other reasons____

High School Information

Name of High School you graduated from______________________________

Location________________________________Year Graduated__________

Approximate Size: under 250_____, 250-500____, 500-1000____,
1000-2000_____, 2000-3000____, over 3000_____

Ranges of Grades (check one): K-12____; 7-12____; 9-12____; 10-12_____

Have you ever taken an Earth Science course? (Astronomy, Geology, Meteorology, Oceanography, or Space Science) Yes____, No_____

Where______________________________________ When______________
(City or College) (State) (Year)

Did it include laboratory exercises? Yes_____, No______

What text (s) was or were used?_________________________________

Did you participate in any of the following courses in High School?

	(Check one) Yes	No		(Check one) Yes	No
HPP Physics	___	___	ECCP Eng. Concepts	___	___
PSSC Physics	___	___	IPS Physical Science	___	___
BSCS Biology	___	___	SSSP Time, Space, Matter	___	___
CHEMS Chemistry	___	___	ESCP Earth Science	___	___
CBA Chemistry	___	___			

Approximately how many years (1 semester = ½ year) have you had in the following courses:

High School (check one) Grades 7-12	0	½	1	1½	2	More than 2		Indicate Grade Level 7	8	9	10	11	12
Biology	___	___	___	___	___	___		___	___	___	___	___	___
Chemistry	___	___	___	___	___	___		___	___	___	___	___	___
General Science	___	___	___	___	___	___		___	___	___	___	___	___
Geology or Earth Science	___	___	___	___	___	___		___	___	___	___	___	___
Algebra	___	___	___	___	___	___		___	___	___	___	___	___
Trigonometry	___	___	___	___	___	___		___	___	___	___	___	___
Geometry	___	___	___	___	___	___		___	___	___	___	___	___
Physics	___	___	___	___	___	___		___	___	___	___	___	___

Your approximate overall senior high school grade standing (Grades 9-12)

D_____, D+_____, C_____, C+_____, B-_____, B_____, B+_____, A_____

Did your parents graduate from high school: Mother_____ Father_____

College Information

How certain are you of your college objective or major? Dead sure_____, Pretty definite_____, Have an idea_____, Totally blank_____

Why did you come to college? Parental pressure_____, Personal decision _____, Other (explain)_____________________

Classification (check one) Fr._____, Soph._____, Jr._____, Sr._____ Uncl._____, Grad._____

College (check One) UC _____, A & S_____, Educ._____, Engr._____ Law_____, Phar._____, FA_____, Grad._____

Principal College Objective or Major (Write undecided if so)_____________

Minor(s) (if known)_____________________________

Approximately how many semesters, college credit, have you had in the following courses (prior to this semester):

College	(Check One) 0	1	2	3	4	More Than 4	Indicate Level Fr.	Soph.	Jr.	Sr.	Other
Biology	___	___	___	___	___	___	___	___	___	___	___
Chemistry	___	___	___	___	___	___	___	___	___	___	___
Geography	___	___	___	___	___	___	___	___	___	___	___
Geology	___	___	___	___	___	___	___	___	___	___	___
Mathematics	___	___	___	___	___	___	___	___	___	___	___
Physics	___	___	___	___	___	___	___	___	___	___	___

Did your parents graduate from college: Mother______, Father_________

Do you expect to graduate? Yes_______, No______. If not, why not? Expect to get married_______, expect to go into father's business______, Other (explain)____

Rate the following subject areas in terms of your desire to enroll for courses in each area. Use a one (1) to five (5) scale to indicate level of desire with 1 = No Desire, 2 = Little Desire, 3 = Medium Desire, 4 = Strong Desire, 5 = Very Strong Desire.

( ) Physics
( ) Biology
( ) Art
( ) Education (Teacher)
( ) Speech
( ) Chemistry
( ) Music
( ) Mathematics
( ) English
( ) Engineering
( ) Government
( ) Sociology
( ) Philosophy
( ) Physical Ed.
( ) Economics
( ) Dance
( ) Geology
( ) History
( ) Geography
( ) Dramatics
( ) Foreign Language
( ) Journalism

List other subject areas in which you have a desire to enroll.

APPENDIX C

Name_________________________________ Date___________________

GEOLOGY I, LABORATORY ACTIVITY #1

Topographic Maps

Purpose

To inquire into the following questions.

1. How are topographic maps constructed?
2. What kinds of information do topographic maps contain?
3. How does one read and interpret a topographic map?
4. What are the uses and limitations of topographic maps?

PART I

Construction of a Simple Topographic Map

Materials

Plastic tray with cover, 2 clear plastic sheets, relief model of volcano, crayon or grease pencil and a ruler.

Suggested Procedure

1. Using a spacing of ¼ inch, mark a vertical series of short horizontal lines on any side of the plastic tray.
2. Place the relief model in the tray and pour water up to the first vertical line.
3. Trace the water-line on the relief model with the crayon.
4. Repeat the procedure for the rest of the markings.

5. Remove the water from the tray, place the cover on the tray and place a plastic sheet on the cover.

6. Looking through the plastic sheet, trace the water-lines as they appear projected onto the cover. Repeat the same procedure on the other sheet, but trace only every other water-line.

Questions

1. The lines you drew on the relief model and on the plastic sheet are called contour lines. In your own words, state a simple definition of a contour line.

2. The interval between contour lines is called the contour interval. State a concise definition of contour interval.

3. Compare the topographic map os the relief model that would result when a vertical interval of only ¼ inch was used with the topographic map based on a vertical interval of ½ inch.

4. Using the bottom of the relief model as 2000 feet above sea level, and if each ¼ inch of water represented 50 feet, what would be the elevation of the top of the volcano?

5. (a) Using the number of contour intervals on your first map, determine the approximate contour interval (in feet), if the distance from the base of the volcano to the top is 600 feet.
   (b) Label each contour line with its correct elevation.

7. The relief model represents an area located in New Mexico, not far west of the Oklahoma state line. Describe one or more ways of constructing a topographic map of the area.

Part II

Reading and Interpretation of a Topographic Map

Materials

Topographic map of the Norman Quadrangle.

1. What is the scale of the map?

2. What is the contour interval of the map?

3. Latitude is measured in terms of degrees, minutes and seconds north or south of the equator, and Longitude is measured in degrees, minutes and seconds east or west of a line passing through the geographic poles and Greenwich, England. For example, Washington, D.C. is located 38°15'N Latitude and 77°1'W Longitude. What is the Latitude and Longitude of Norman, Oklahoma?

4. What is the location, Latitude and Longitude, of the point of lowest elevation? What reference feature is nearby and why would you expect this to be true of most topographic maps?

5. What part of the map (N.E. ¼, E ½ S.W. ¼, etc.) is characterized by relatively flat surface with a 40 to 50 foot, sharp drop in elevation?

6. What part of the map has the most irregular surface?

7. How does Bishop Creek, south of Norman, differ from some of the un-named streams along the eastern side of the map?

8. Describe the general drainage pattern of the streams on the map. (The stream north-west of Noble is a good example.)

9. Explain the origin of the numerous bodies of water on the map.

10. Why do the roads extending north-south and east-west form squares, i.e., why are they so uniform in distribution?

11. A triangle, with a dot in the center, labeled B.M., is shown between the north-west corner of the Armory and the southeast corner of the Business Administration Building. Explain. Try to locate it on the ground before our next lab session.

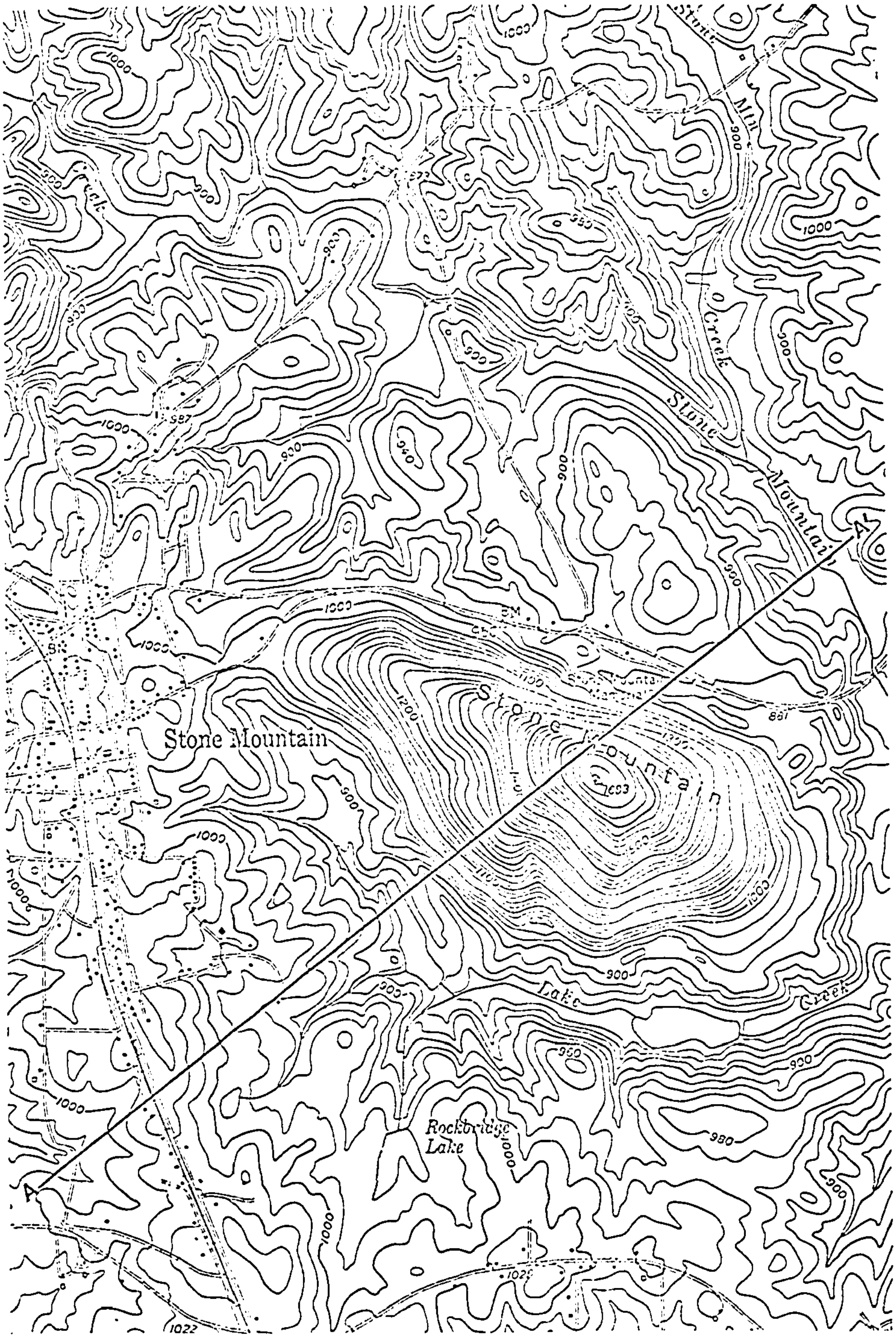
12. Give the approximate elevation of the playing field in Owen Stadium.

13. Keeping the same size map paper, what would be the effect of constructing the map to a <u>larger</u> scale?

14. What does the dotted line just north of Goldsby indicate?

15. What is the general direction of water flow in the Canadian River? How can you tell by looking at the map?

16. Describe two methods of stating the location of Noble, other than by latitude and longitude.



(After W.K. Hamblin and J.D. Howard, 1967,p.69)

PART III

Characteristic of Contour Lines

Materials

One xeroxed map, size 8½" X 11", to be furnished by your instructor.

Procedure

Study the contour lines on the map and list as many of their characteristics as possible. Refer to the pattern formed by more than one contour line as well as to individual contour lines.

1. For example: Contour lines bend or V upstream when crossing a river or stream.

REFERENCES

1. Freeman lab sheet # 217, pp. 1-4.
2. Your Topographic Maps brochure.
3. Text book, Leeds & Judson: Appendix D.

GEOLOGY I, LABORATORY ACTIVITY #2

Volcanism

Purpose

To inquire into the following questions.

1. What is the origin of volcanic materials?
2. Why does the material come to or near the surface?
3. What kinds of rocks are associated with volcanism?
4. What landforms are associated with volcanism or result from long periods of weathering and erosion following volcanism?
5. What kinds of localities have the greatest probability of producing volcanism?

PART I

"Volcano Surtsey"

"Volcano Surtsey" is a 26-minute 16mm film, with sound and color, of a volcanic eruption that appeared November 14, 1963, in the sea near Iceland. The film is a winner of the Bronze Bucarium at the 11th International Exhibition of Scientific-Didactic Films, University of Padua, "for the complete documentation of the birth of a volcano obtained with exceptionally rigorous cinematography."

As you view the film, try to keep the above questions in mind and record some of your observations and subsequent concepts.

PART II

Stereo-aerial Photographs and Topographic Maps

Materials

Stereo-aerial photograph booklet, stereoscope, ruler, topographic maps as indicated.

PLATE #54 and KOKO HEAD QUADRANGLE

Your instructor will help you with the proper use of the stereoscopes (please handle them carefully) and stereogram. Read the explanation found below the stereogram before attempting to answer the following questions. After you have become familiar with the stereogram, turn it upside down so its orientation corresponds to the topographic map. (North is always toward the top of the topographic map.)

1. How many depressions does Koko Head show in stereo? Locate and name their depression contours as labeled on the topographic map.

2. Briefly explain the origin of Koko Head's Hanauma Bay.

3. Explain the origin of the grooves on the south and southwest side of Koko Crater.

4. The scale of the stereogram is 1:49,000. What is the approximate diameter (in feet) of Koko Crater? Check the answer by referring to the topographic map and the proper scale.

5. Koko Head, Kahauha, Koko Crater and Manana Island tend to form a straight line. Why?

6. What is the least number of eruptions in the history of Koko Head?

PLATE #55 and MT. RAINIER NATIONAL PARK

7. Why does Mt. Rainier have glaciers while so many other volcanic cones throughout the world lack them?

8. About how many feet are represented by 1 inch on the photo? On the map?

9. Note and record the contour interval. Study and compare the photo and the map, but do not write about it.

10. Describe the drainage pattern.

PLATE # 56 and CRATER LAKE NATIONAL PARK

11. How may one explain the origin of Kerr Notch, Sun Notch and Munson Valley Notch, on the righthand stereogram and along the south edge of Crater Lake on the map?

12. What is the approximate diameter of Crater Lake?

13. Give two possible explanations of how Crater Lake Basin formed.

14. Explain the origin of the conical shaped hills on the flanks of Mount Mazama; e.g., north of Crater Lake and clockwise: Timber Crater, Bear Butte, Pothole Butte, Crater Peak and Goose Nest.

15. Which is older, Crater Lake Basin or Wizard Island?

16. Notice how close together the contour lines are around Crater Lake.

PLATE #57 and SHIPROCK QUADRANGLE

17. What is the feature labeled Shiprock?

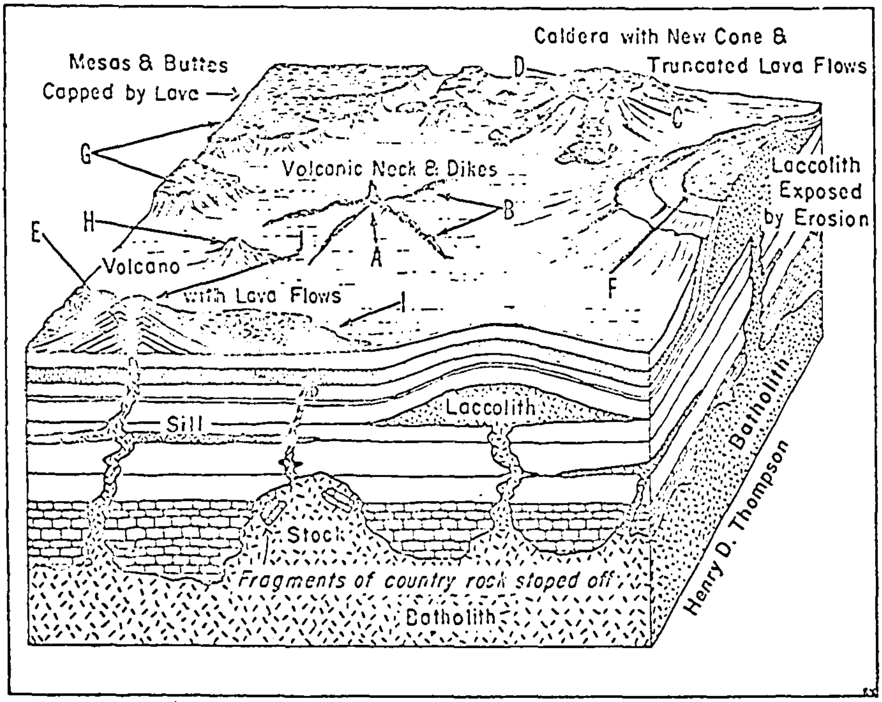
18. How many radial dikes can you see on the stereogram? On the map?

19. Why haven't the dikes been eroded level?

*NOTE: Before returning your stereo-photo booklet and stereoscopes, look at Plate #50. This will be the area referred to in your take-home exercise, Part IV.

PART III

Landforms and Rocks Associated With Volcanism



Vulcanism. (Courtesy Henry D. Thompson)

Landforms developed on crystalline basements as described in the previous chapter include those associated with large igneous intrusions. Extrusive rocks include a wide range of materials with equally extensive ranges of physical appearance, mineral composition and resistance to weathering. Extrusions may assume physical forms varying from widespread deposits of fine ash to massive lava flows, depending mainly upon the mineral composition of the extruded material. Basaltic magma tends to form the large flows due to its non-violent issuance from the volcano. Acidic (rhyolite) magma is most often ejected violently during the release of superheated gases and reaches the surface as cinder and ash. Extrusive features are formed on the surface and their forms are immediately apparent. Intrusive features, having formed beneath the surface, may be observed only when erosion strips away the burden of material above them.

Shiprock (A) is a volcanic neck with radial dikes (B). Molten rock forced its way up through the conduit and fissures of the volcano and cooled to form a fine-grained basalt. Activity ceased and erosion stripped away the material forming the old cone. The more resistant basalt remained to produce the neck and thin, nearly vertical dikes.

Some difference of opinion exists regarding the formation of volcanic caldera such as Crater Lake (D). The controversy poses the problem of whether these great depressions are explosive in nature or whether they are the result of a large scale collapse of the volcano cone into its own interior. A composite of these two arguments probably approaches the truth. Crater Lake is formed from the remains of ancestral Mt. Mazama, a volcano which stood some 12,000 feet high. Its diameter of about 5½ miles is typical. The rim rises 500 to 2,000 feet above the lake which is as much as 2,000 feet deep. Wizard Island (C) is a small cinder cone resulting from eruptions through the caldera floor.

(After J.L. Scovel <u>et al.</u>, 1966, p.61)

Directions

You will find several specimens of igneous rocks in labeled trays at the front of the room. Examine each type, record its name, state where it formed (on the surface in association with a lava flow or a volcano, below the surface in dikes, sills or edges of laccoliths, deep below the surface in a batholith) and if possible state some clues on which you base your observations. For example: Pumice. Formed on or above the earth's surface where it cooled to form a glass and trap gas bubbles.

PART IV

Contouring and Constructing a Profile

Directions:

Elevations of numerous positions on Plate # 50 have been plotted on the following sheet. Using a contour interval of 50 feet, draw the contour lines to form a topographic map.

The last page of this exercise is provided for constructing a profile along line A-A', of the topographic map that you completed above. Refer to the Freeman Lab Sheet # 217 and Appendix D in your text for help in contouring and constructing a profile.

REFERENCES

1. Freeman Lab Sheets #226 and #217.
2. Textbook, Leeds and Judson, pp. 43-63, and Appendix D.

GEOLOGY I, LABORATORY ACTIVITY #3

Minerals

Purpose

To inquire into the following questions.

1. What conditions are necessary for mineral formation?

2. How do minerals "grow"?

3. What factors influence a mineral's chemical and physical properties; e.g., density, cleavage, hardness, solubility, etc?

4. What techniques may be used to identify minerals?

PART I

Film - "Rocks That Originate Underground"

Today's film explores the origin of volcanic, plutonic, and metamorphic rocks. You are asked to pay special attention to the section on atomic arrangements, cooling rates, crystal growth and the relationship between rocks and minerals. The overall contents of the film will help you answer some of the above questions as well as provide a foundation for today's laboratory activity.

PART II

Atomic Arrangement and Mineral Properties

Materials

Atomic model kits and display models of atomic arrangements.

The small marble represents an atom of silicon, and the larger styrofoam sphere represents an atom of oxygen. According to the basic principles of chemistry, the silicon atom is capable of attaching (bonding) itself to four oxygen atoms. Two silicon atoms may also share an oxygen atom as more silicon and oxygen atoms combine to form chains and sheets toward the formation of those minerals known as silicates. The most stable configuration will occur when the four oxygen atoms are in contact with the silicon atom.

Making use of the atomic models and the above information, construct the basic "building block" of the silicate minerals.

1. Sketch the structure or draw a diagram indicating the relative location of the atomic centers.

2. Combine two of the "building blocks". (Remember that two silicon may share a common oxygen.) Sketch the configuration or draw a diagram indicating the relative location of the atomic centers.

Examine the models of various atomic arrangements in different minerals and compare the model with the mineral specimen.

3. Why do the minerals calcite and halite exhibit such good cleavage? Does this answer apply to cleavage in general? Explain.

4. Why do minerals vary in degree of hardness?

5. Why do minerals vary in density? (Density is the amount of mass divided by its volume.)

PART III

Identification of Minerals

Materials

Eighteen different minerals, streak plate, thumb nail, penny piece of glass, knife blade and file.

Refer to the Freeman Lab Sheet. Concentrate on the identification of quartz, feldspar, muscovite, biotite, hornblende and olivine, but also study the other minerals.

REFERENCES

1. Freeman Lab Sheet #213.
2. Textbook, pp. 31-42 and Appendix C.

GEOLOGY I, LABORATORY ACTIVITY #4

Igneous Rock

Purpose

To inquire into the following questions.

1. Where do the materials of igneous rocks originate?

2. What factors influence the (texture) size, shape and arrangement of the crystals in igneous rocks?

3. How are igneous rocks identified?

4. How are igneous rocks classified?

5. What kinds of information do geologists obtain from the study of igneous rocks?

PART I

Study and Identification Rock Fragments

During the past two laboratory activities you have had an opportunity to view two films ("Volcano Surtsey" and "Rocks That Originate Underground") and work with some rocks and minerals. You are now asked to reflect back to those lab activities in an attempt to draw relationships between rocks and minerals, how and where they form.

Materials

Fragments of crushed igneous rock, teasing needle and magnifier.

Separate the fragments into piles so that each pile contains about the same kind of fragments.

1. How many piles did you isolate?

2. Study the fragments in each pile (pile #1, pile #2, etc.) and record your description of the fragments - color, shape, type of edges, cleavage, hardness if possible, luster, etc.

3. Have you seen similar fragments before? Where? Attempt to identify the fragments by name? What is the one term that would apply to all of these fragments?

4. You will find several specimens of igneous rocks on the front desk. Which one contains the same kind of fragments that you have been studying? Name it.

5. On the basis of the above study, make a statement concerning the relation between rocks and minerals.

6. When what is referred to here as "fragments" are found in igenous rocks, they are called crystals. Why don"t we see crystals in all igneous rocks?

PART II

Classification of Igneous Rocks

7. Study the igneous rocks, and on the basis of light color, dark color, coarse grained, fine grained and glassy appearance, construct a simple classification chart. Draw it on a separate piece of paper so that it extends over at least half of the page.

8. Look at the minerals in your upper righthand desk drawer. Separate quartz, feldspars, muscovite, biotite, hornblende and olivine into two categories, light colored and dark colored.

9. On the basis of the above categories, indicate what minerals would predominate in each of the igneous rocks. List these on or near the chart of classification of igneous rocks, so they refer to the named rock.

10. What factor(s) will determine whether an igneous rock will be coarse grained, fine grained or glassy?

11. Practice until you are able to identify all of the above igneous rocks.

REFERENCES

1. Textbook: pages 59-71.

GEOLOGY I, LABORATORY ACTIVITY #5

Sedimentary and Metamorphic Rocks

Purpose

To inquire into the following questions.

1. Where do the materials of sedimentary rocks originate?
2. How are the materials of sedimentary rocks transported?
3. Where are the materials of sedimentary rocks usually deposited?
4. What determines the "hardness" (durability) of sedimentary rocks?
5. How are sedimentary rocks identified and classified?
6. What kinds of information do geologists obtain from the study of sedimentary rocks?
7. What are the conditions for metamorphism?
8. How are metamorphic rocks identified and classified?
9. What kinds of information do geologists obtain from the study of metamorphic rocks?

PART I

Movie - "Why Do We Still Have Mountains?"

The last part of your last laboratory period was devoted to a movie, "Rocks That Form on the Surface of the Earth," which presented many concepts concerning sedimentary rocks - concepts that will be most helpful in today's lab session. This morning we are going to view the movie "Why Do We Still Have Mountains?" In addition to answering the question in its title, this movie will also provide some insight into the formation of metamorphic rocks and should also prove helpful in today's lab.

PART II

Sedimentary Rocks

Sedimentary rocks are formed at the surface of the earth as a result of two basic processes: mechanical deposition of rock, mineral and shell fragments, and chemical precipitation of crystalline particles.

The first process, mechanical deposition, is preceded by the weathering and erosion of the materials in source area. After transportation (erosion) and deposition, the weathered rock particles (sediments) are converted into hard sedimentary rock by lithification, that is, compaction of loose sedimentary particles and their cementation by mineral matter precipitated from interstitial water.

The second process, chemical precipitation, may be preceded by the transportation of chemicals in solution to the site of deposition, or the chemicals could originate in or near the area of deposition through secretion by plants or animals.

Examination of many of the sedimentary rocks of this part of Oklahoma suggest that their source area was the Rocky Mountains to the northwest, or in some cases the Ouachita Mountains to the east.

1. What clues would a geologist look for when attempting to associate sedimentary rocks with a possible source area?

2. What relationship, in terms of elevation, exists between the source area and the area of deposition?

3. List all the possible forces and/or agents that are capable of transporting sediments from a source area to an area of deposition.

Examine the specimens of unweathered granite and the specimen weathered granite that are on the front desk. Remember the fragments that you observed last week!

Now look at the samples of conglomerate, crushed sandstone, wind blown sand and sandstone. (Use your hand lens and microscope when appropriate.) Sediments are said to be well sorted when they are all the same size, and unsorted when they vary greatly in size.

4. Based on your above observations, what happens to sediments while they are being transported? That is, how do they change?

5. List the well sorted materials observed. List the unsorted materials observed.

6. What clues do sedimentary rocks (say sandstone) contain concerning their history?

Take a piece of shale, granite and sandstone, and place a few drops of water on each one. Observe how fast the water is absorbed by each rock. The rate of water passing through a rock is a measure of the rock's permeability.

7. List the above rocks in order of highest to lowest permeability.

8. If permeability tends to accelerate chemical weathering, all other conditions constant; which one of the above rocks will weather the fastest?

9. Devise a simple classification system for shale, sandstone, conglomerate and limestone.

10. Be able to identify the following sedimentary rocks: shale, sandstone, conglomerate and limestone.

PART III

Metamorphic Rocks

Metamorphic rocks are the product of a fundamental change in pre-existing rocks. Intense heat radiated from an intruding mass of magma causes contact metamorphism of the intruded rocks within a relatively narrow zone adjacent to the contact. Regional metamorphism, which affects very large areas, is caused by the effects of both pressure and heat upon deeply buried rocks. In both types of metamorphism, fluids in the rock may help bring about chemical changes. Water is the principal fluid, but in addition, such chemical elements as chlorine, fluorine, boron, and others may emanate from molten intrusive masses and react with the surrounding rocks.

Metamorphism takes place in an environment that may be quite different from the one in which the original rock was formed. Many minerals are stable only within limited ranges of pressure, temperature, and chemical conditions. The mineral composition and texture of sedimentary rocks, for example, are adjusted to a surface or near-surface environment. If the rock is subjected to temperatures and pressures much higher than those at the surface, the limits of stability of the minerals may be exceeded; mechanical and chemical readjustments may then occur in the rock, producing new minerals that are stable under the changed conditions, or altering rock texture, or both. It follows from this that plutonic rocks, having formed under conditions of great heat and pressure, should be less affected by metamorphism than most sedimentary rocks.

The effects of metamorphism include: (1) deformation and reorientation of mineral grains, (2) recrystallization of minerals into larger grains, and (3) chemical recombination and growth of new minerals, with or without the addition of new elements from circulating fluids. The amount of alteration depends also on the composition and texture of the original rock. Intense metamorphism may cuase a complete transformation of texture and mineral composition, whereas a slightly metamorphosed rock may be difficult to distinguish from the original igneous or sedimentary rock. All transitions between these two extremes occur in nature.

11. What are the conditions for metamorphism?

12. Be able to identify the following metamorphic rocks: slate, schist, gneiss and marble.

REFERENCES

1. Textbook: pages 91-110 (Sedimentary Rocks)
   pages 278-290 (Metamorphic Rocks)

GEOLOGY I, LABORATORY ACTIVITY #6

Deformation of Strata and Construction of a Geologic Map

Purpose

To inquire into the following questions.

1. What is the origin of the tensional and compressive forces in and on the earth's crust?

2. How are incompetent beds (inherently weak strata) affected by compressional forces, by tensional forces?

3. How are competent beds (inherently strong strata) affected by compressional forces, by tensional forces?

4. How are the effects of crustal deformation, followed by weathering and erosion, represented on a geologic map?

PART I

Incompetent Beds Under Compressional Forces

Materials

Squeeze box, sand, flour, clay layer, protractor and cardboard.

Procedure

1. Place a piece of cardboard about one and one-half inches behind the glass front and gently squeeze the ends of the cardboard by turning the threaded shaft inward.

2. Now proceed to alternate several (4 or 5) ½-inch layers of sand with trace layers of flour between the cardboard and the glass, while supporting the back of the cardboard with sand. Stop when the layers exceed a little more than halfway up the glass front.

3. Gently remove the cardboard partition by pulling it straight up.

4. Sketch the view through the glass. (Sketch "A") Number the beds on both ends of the sketch.

5. Turn the handle on the thread shaft so as to compress the sand, but stop periodically to sketch the view through the glass. Record in sketch "B" and sketch "C".

6. Stop turning the handle before the sand overflows.

SKETCH

(A)

(B)

(C)

Questions

1. Measure the angle between the plane of broken beds and the bottom of the box. Record ________.

2. The geologic processes of weathering and erosion work to reduce areas of high elevation and fill in the areas of low elevation. In the above activity, assume that the beds that were thrusted upward were also weathered and eroded down to the original elevation that existed prior to compression.

   (a) Sketch, on another piece of paper, how the surface would look from above.

   (b) Label the exposed beds with their original numbers.

   (c) Also indicate, with an arrow, the direction in which the plane of broken beds dip below the surface.

   (d) Indicate, on the sketch, the younger and older beds.

   (e) What is the relationship between the up-thrown beds and the relative age of the beds exposed on the surface after erosion?

   (Dump all of the sand back into the large cardboard box.)

PART II

Competent Beds Under Compressional Forces

Procedure

Place about one inch of sand in the box and cover it with the clay layer. Mark the edge of the clay layer, along the side against the glass, with flour. Cover the clay layer with sand until the box is about 3/4 full.

Compress the sand and clay layer by turning the threaded shaft as you did in Part I. DO NOT COMPRESS THE LAYERS TOO MUCH! Sketch the view through the front glass. Sketch "D".

(D)

(4) Compare the behavior of incompetent beds and competent beds when placed under compressive forces.

(Dump all of the sand into the large cardboard box.)

PART III

Incompetent Beds Under Tensional Forces

1. Place the piece of cardboard, <u>on end</u>, about one and one-half inches behind the glass front as you did in part one.

2. <u>PACK</u> three alternate one-inch layers of sand and trace layers of flour in the space between the cardboard and the glass front. Support the back of the cardboard with sand and continue to fill the box almost to the top.

3. Gently remove the cardboard.

4. Sketch the view through the glass. (Sketch "E")

5. Turn the handle so that the threaded shaft moves out of the box. If the "sliding board" sticks, push it away from the sand-layers by hand.

6. Sketch the pattern as it now appears through the glass. (Sketch "F")

7. Measure and record the angle between the plane of broken beds and the bottom of the box.

8. Refer to the above activity and, assuming the same conditions in Question #2, answer questions 2A through 2E.

(E)

(F)

REFERENCES

1. Freeman Lab Sheet #218
2. Textbook: pp. 248-258, pp. 378-379

GEOLOGY I, LABORATORY ACTIVITY #7

Structural Geology

Purpose

To inquire into the following questions.

1. What forces and processes act on the earth's crust?

2. How is the structure of the earth's crust changed?

3. How does a geologist detect change in the earth's crust?

4. What information is conveyed by a geologic map, a cross-section?

5. What is meant by "strike and dip"?

Introduction

An important part of the geologist's work is concerned with the determination of the present distribution and orientation of rock types, and the explanation in terms of the historical events which produced the present conditions. If one has an understanding of the many ways horizontal strata can be changed, he may use his knowledge to reconstruct a series of events that account for the present position and conditions of the rocks in a given area.

This activity is designed to provide you with an opportunity to visualize many ways in which horizontal strata can be changed and how the resulting patterns appear in map-view (view from above) and cross-section (edge view).

Materials

Four different colors of clay, plastic knife, corn starch, bottle-type rolling-pin, pencil and paper.

DIRECTIONS

Rollout four separate layers of clay, 1/4 inch thick by 6 inches wide by 8 inches long, each of a different color. Sprinkle very little corn starch on the layers as you stack them on top of each other. (The corn starch prevents the clay from sticking.) Cut the edges so that all of the layers are the same size.

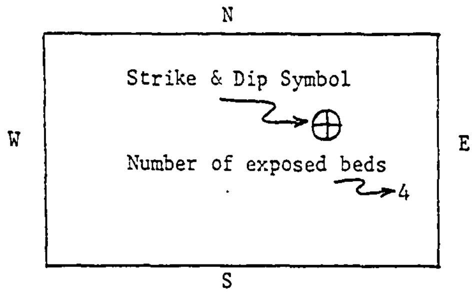
You will be assigned to one of the following numbered problems. In each case, you are asked to start with horizontal beds (clay layers), change them as indicated and draw the map-view and cross-section. **Number all bed(s) and label the youngest and oldest beds on both the map-view and the cross-section. Show the correct strike and dip symbol on all map-views.

After you have finished your assigned problem, orient the clay model in respect to north (assume north to be toward the front of the room), label the model with its number so that other students may associate it with the correct problem, and then proceed to move about the lab and draw a map-view and cross-section of each completed model.

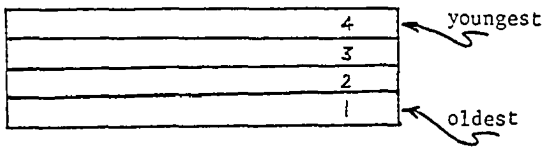
Example #1

Horizontal beds (not tilted, folded nor eroded.)

Map-view

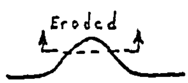


Cross-section



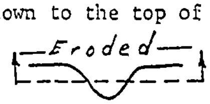
Example #2 is located on the following page.

3. Horizontal beds compressed between East and West along the long axis, unwarped in the center and eroded through the top two beds and part of the third bed.



4. Horizontal beds compressed between East and West along the short axis, upwarped in the center to produce a north plunging fold and eroded through the top two beds and part of the third bed.

5. Horizontal beds compressed along the East-West long axis, downwarped in the center and eroded down to the top of the limbs.

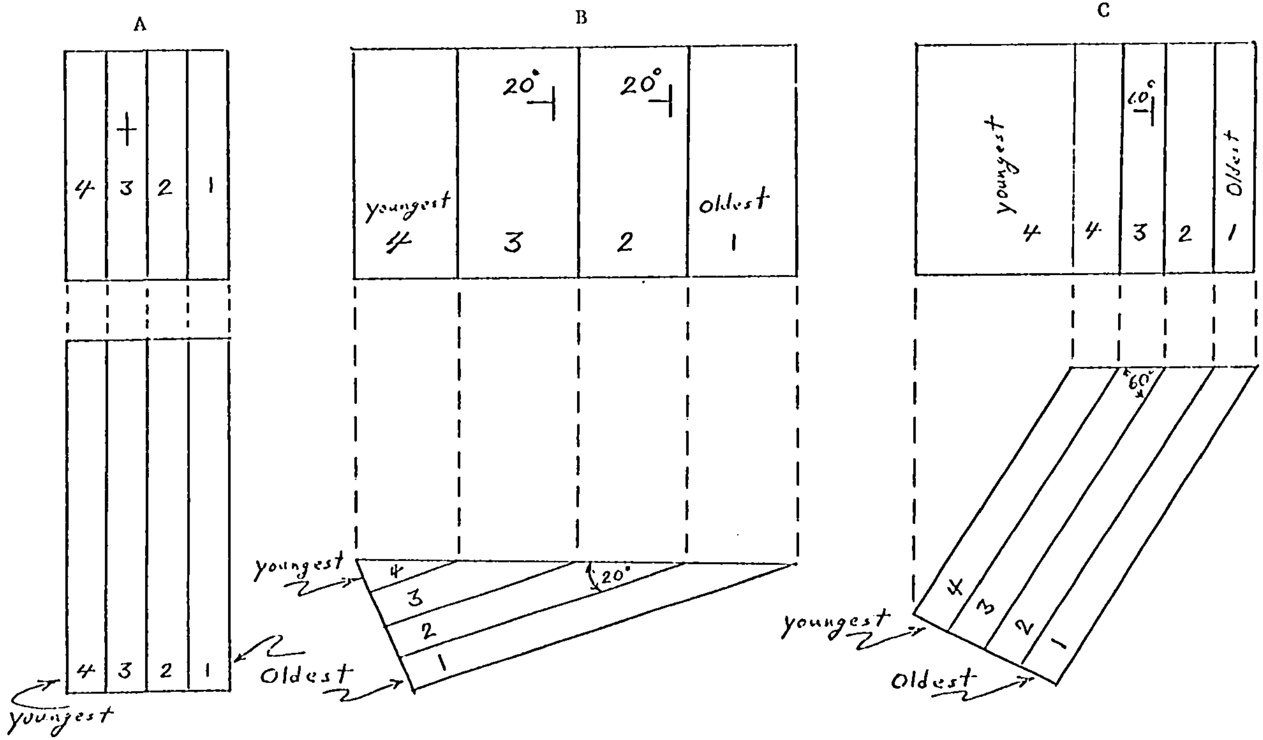


6. Horizontal beds compressed along the East-West short axis, downwarped in the center to produce a south plunging folding and eroded through the top two beds and into part of the third bed.

7. Horizontal beds cut by a north-south trending fault plane dipping 45° to the east, with the east side offset upward one bed and then eroded to the original surface. (Show the direction and amount of dip of the fault plane on the map-view.)

Example #2

(A) Horizontal beds tilted up 90° in the east and eroded level.
(B) Tilted 20° and eroded level.
(C) Tilted 60° and eroded level.



8. Horizontal beds cut by a north-south trending fault plane dipping 45° to the west, with the east side offset one bed upward and eroded level with the original surface. (Show the direction and amount of dip of the fault plane on the map-view.)

9. Horizontal beds tilted 90° from the south cut by a north-south trending vertical fault plane offsetting the east side one and one-half beds to the north.

10. Horizontal beds tilted upward in the east, eroded from the top west edge of the top bed to the lower east edge of the bottom bed, followed by deposition of two more beds.

QUESTIONS

1. Study example #2, A, B and C. What is the relationship between the angle of tilt and the apparent thickness of the beds on the surface after erosion.

2. Refer to page 5 of your Freeman Series #218 and place the symbol for the axial trace and direction of plunge on the map-views of problems #4 and #6.

3. What is the relationship between the age of the rocks on the upthrown side of a fault and those on the downthrown side of the fault after erosion? (Refers to problems #7 and #8.)

4. List all the ways that horizontal beds can be changed.

References

Freeman Lab Sheet: #218
Textbook: pp. 248-258

GEOLOGY I, LABORATORY ACTIVITY #8

Development of Land Forms - Horizontal Strata

Purpose

To inquire into the following questions

1. What processes play a part in the development of land forms?

2. What processes predominate in an arid region? In a humid region?

3. What land forms develop on horizontal strata in an arid region? In a humid region?

4. What are the stages in the regional cycle of erosion and what are the criteria for each stage?

5. What is the relationship between structure and land form?

6. How may maps and aerial photographs be utilized in the identification and study of land forms?

PART I

Color Slides Depicting Results of Weathering and Erosion

Your instructor will project several color slides on the screen. As each slide is projected, record the type of weathering and/or erosion and briefly state the necessary prevailing conditions.

PART II

Color Slides Showing Land Forms of Horizontal Strata

Color slides showing features and land forms of horizontal strata will be projected on the screen. The names of the features and land forms will be given, but you will be asked to explain how the land form developed; i.e., the historical sequence of events that led to the development of the land form.

PART III

Aerial Stereo - Photographs of Land Forms and Related Topographic Maps

Study each photo and map, and read the summary at the bottom of each photo before attempting to answer the following questions.

PLATE #45 Cuny Table, South Dakota
Cuny Table Map

1. In what stage of erosional cycle would you classify this land form? Upon what criteria did you base your decision?

2. What is the term given to the highly dissected topography found on the northeast corner of the map and photo?

3. How would you classify the climate of this region arid, semi-arid, or humid? What are the clues?

4. Sketch an idealized east-west cross-section from 2.5 to 2.5 on the boarder scale. Show at least five beds and list (1, 2, 3, etc.) the historical events that led to its formation since time of first deposition.

PLATE #41 Red Wash, New Mexico
Rattlesnake Quadrangle Map

Red Wash photo covers the area just north of the latitude-longitude intersection (Lat. 36°50' N; Long. 108°55' W)

5. How can you explain the water in Red Wash photo when the map fails to indicate the presence of water?

6. How high (elevation in feet) is it from the lowest point in Red Wash to the top edge of the plateau (to the west on the map, upper one-fourth on the photo)?

7. Classify this area according to the stages of the erosional cycle. What is the climate of the region? What are the clues?

8. The San Juan River is referred to as braided. What factors produce a braided river? Giver the general direction of flow for the San Juan River.

PLATE #39 Marble Canyon, Arizona
Vishnu Temple Quadrangle

9. How high above the Colorado River is Desert View, edge of Coconino Plateau.

10. What is the distance between Desert View and Cape Royal, edge of Walhalla Plateau?

11. What kind of rock covers the Plateaus?

Take note of the many buttes indicated on the map.

PLATE #40 Bear Creek, South Dakota

12. Classify this area according to the stages of the erosional cycle.

13. What is meant by "headward erosion"?

Take note of the meadering stream, flood plain and emminent cutoffs.

PLATE #60 Indian Creek, South Dakota

14. Classify this area according to the stages of the erosional cycle.

PLATE #43 White River, Colorado

15. Classify this area according to the stages of the erosional cycle. What are the criteria?

PLATE #48 Highland Rim Plateau, Tennessee

16. Classify this area according to the stages of the erosional cycle. How does this topography differ from that of Plate #43? Why?

PLATE #61 Banded Outcrops, Texas

Read the summary and note the "steps" that usually accompany banded outcrops.

Topographic Map - Raton, N. Mexico - Colorado

17. Name the type of drainage pattern in the area.

18. Classify the area according to the stages of the erosional cycle.

Topographic Map - Raton, N. Mexico - Colorado

Note the buttes and mesas; e.g. Black Mesa, Cunningham Butte, Meloche Mesa, Horse Mesa, Bartlett Mesa, etc.

19. Classify this area according to the stages of the erosional cycle. Climate?

Topographic Map - Juanita Arch, Colorado

Note Flat Top Mesa and the banded contour lines.

20. Give the general direction of flow of the Dolores River. Climate?

References

Freeman Lab Sheets on Streams, and Landscape Development.

GEOLOGY I, LABORATORY ACTIVITY #9

Structural Geology

Purpose

To inquire into the following questions.

1. How do individual structrual features appear on a simple geologic map?

2. What information is conveyed by a geologic map?

3. What is the relationship between topographic expression and structure?

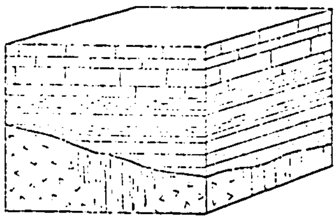
4. How does a geologist construct a geologic map?

PART I

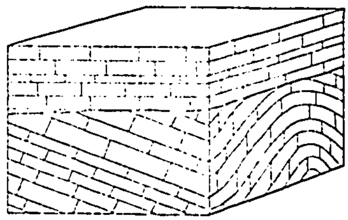
Unconformities

Study the four diagrams of different kinds of unconformities and prepare to discuss them with your lab instructor.

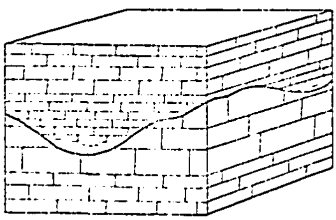
Breaks in the Record



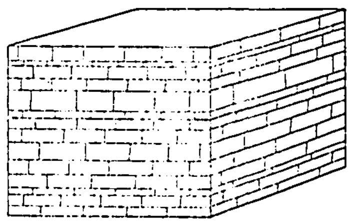
Nonconformity



Angular unconformity



Disconformity



Paraconformity

1. What does each kind of unconformity have in common?

2. How does each unconformity differ from the others?

PART II

Geologic Map of the Mid-Continent

Your lab instructor will help you become familiar with the geologic map. Be sure to read the information <u>both</u> sides of the map before attempting to answer the following questions.

3. Describe what kinds of information are presented in the form of a geologic map.

4. Apply question #3 to a tectonic map.

5. Apply question #3 to a physiographic map.

6. Apply question #3 to cross-sections.

PART III

Geologic Map and Cross-section Cutouts

The following pages contain several structural diagrams which may be cut along the dotted lines and folded on the solid lines to give a three-dimensional structure. Place strike and dip symbols on map views only, and label the oldest and youngest bed. Also use a small arrow to indicate the direction in which the fault plane dips. You are also asked to draw the map views and cross-sections in the outlines provided.

GEOLOGY I, LABORATORY ACTIVITY #10

Development of Landforms - Tilted and Folded Strata

Purpose

To inquire into the following questions.

1. What landforms evolve from tilted strata?

2. What landforms evolve from folded strata?

3. What landforms are associated with the faulting of extensive blocks?

4. How do these landforms appear on stereo-aerial photographs?

5. How do these landforms appear on geologic maps, topographic maps and in cross-section?

PART I

Color Slides of Tilted and Folded Strata

Your instructor will project several color slides on the screen. Study each slide and try to keep them in mind when working today's Lab Activity.

PART II

Stereo-Aerial Photograph of Landforms and Related Topographic Maps

Study each photo and map, and read the summary at the bottom of each photo before attempting to answer the following questions.

PLATE #67 Rattlesnake Ridge, Colorado
Loveland Quadrangle Map
Raised Relief Map

1. What is the general name given to any ridge which tends to be of equal steepness on both sides?

2. How do you account for the valley between the Dakota Sandstone ridge (lower center) and the Niobrara Chalk ridge (upper center)?

3. Sketch a simple geologic map of the area showing oldest and youngest rocks, strike and dip symbols, D.S. (Dakota Sandstone), crystalline rocks and N.C. (Niobrara Chalk). Also sketch a cross-section perpendicular to the ridge and indicate the same rock units.

4. Give a brief account of the historical events that led to the development of this landform.

This plate corresponds to the north-south ridges found in the north central part of the raised relief map. Compare the raised relief map with the topographic map.

PLATE #68 Lookout Ridge, Alaska

5. Sketch a geologic map of the outcrop along the ridge and label it with strike and dip.

6. Explain why the ridge is so steep on the south side.

PLATE #70 Muddy River, Utah

Note the gullies and the direction of dipping strata. Also note the water gap at the top of the photo.

7. What kind of climate prevails in this area?

PLATE #74 Honey Creek, Oklahoma

This plate is optional - you might enjoy seeing a photo of the Arbuckle Mountain area.

PLATE #73 Green Mountain, Wyoming
Sundance Quadrangle

Compare the Sundance Quadrangle Map with Plate #73. Note the other domes and buttes on the topographic map.

8. Sketch a geologic map and cross-section of Green Mountain, showing oldest and youngest rocks, and strike and dip symbols.

   Note the meandering stream in the photo.

9. What is the diameter (in miles) of Green Mountain?

PLATE #47 Cove Mountain, Pennsylvania
Harrisburg Quadrangle

10. Why are rapids so prevalent in the water gap?

11. Use your photo to obtain strike and dip of the resistant sandstone ridge. Orient your photo with the topographic map - Dauphin can be seen on the right side of the photo.

Use a single line to represent the crest of each ridge and label each line with the proper strike and dip symbol.

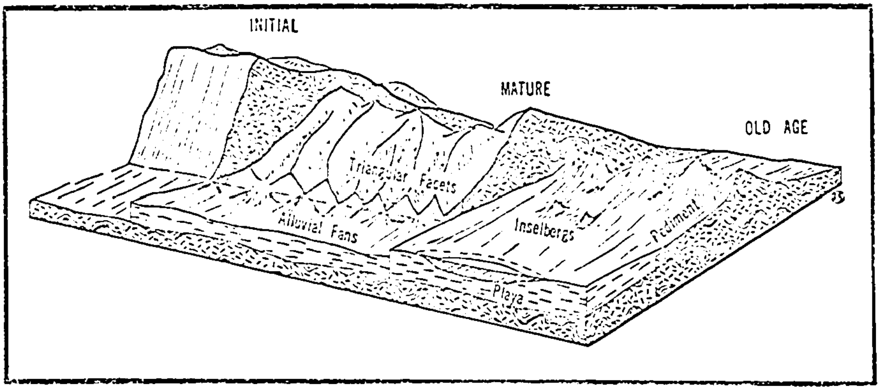
12. Record the climate of the area.

PLATE #71 Ouachita Fold, Arkansas

13. Using a double line, sketch the S - shaped outcrop as seen on the photo. The right limb is dipping to the left. Place strike and dip symbols on the sketch and indicate the oldest and youngest rock.

Extra credit: Draw a cross-section that cuts across the three limbs.

The next three plates and several topographic maps display landforms that result from block faulting, i.e., extensive blocks (big enough to be considered mountains) are pushed upward, or in the case of a graben, faulted downward to form valleys which do not drain into the ocean but lose their water by evaporation. The following diagram illustrates the landforms and stages that you should take note of in the following photos and maps.



(After W.M. Davis)
The Erosional Cycle on an Arid Fault Block.

Topographic Map - Shell Peaks, Nevada

14. Note the shape change in elevation along the right side of the map. Record the elevation in the valley and on the fault block. Note the straight edge of the block along the west side of the valley.

15. Notice the river pattern on the fan-shaped landform at the base of the dissected fault block. What is the fan called?

16. List evidence to support an arid climate.

17. Record the highest and lowest elevations found on the topographic map.

Study PLATES #27 and #26 in conjunction with the Antelope Peak, Arizona topographic map.

18. Give a brief sketch of how this landform developed.

REFERENCES

1. Freeman Lab Sheet on Landscape Development

GEOLOGY I, LABORATORY ACTIVITY #11

Development of Landforms - Streams and Ground Water

Purpose

To inquire into the following questions.

1. What are the stages of the stream erosional cycle?
2. What landforms are associated with each erosional stage?
3. How do these landforms appear as photographs, on topographic maps and on stereo - aerial photographs?

PART I

Color Slides of Streams and Related Landforms

Your instructor will project several color slides on the screen. Study each slide and try to keep them in mind when working today's lab activity.

PART II

Stereo - Aerial Photographs of Landforms and Related Topographic Maps

We have already studied some streams in relation to horizontal and folded strata. Today's lab activity will focus more directly on streams and their associated landforms. It is important that you be familiar with the introductions to the Freeman Lab Sheets #220 and #221, especially #221 on Landscape Development. Also review, if necessary, the stereo - aerial photographs on Stream Erosion and Erosion Cycles, PLATES #39 through #48.

Study each photo and map, and read the summary at the bottom of each photo before attempting the following questions.

PLATE #44 The Loop-Entrenched Meander, Utah
Carlisle 3 NE, Utah Map

Notice the imminent cutoff and meander core on the Colorado River.

1. Meanders develop on flood plains. How do you explain the entrenched meanders in rigid bedrock?
2. How far below the plateau (N.W. side of map) has the Colorado River eroded? In feet_____.

PLATE #49 Obey River - Two erosion cycles

3. What evidence supports uplift in the history of this area?

PLATE #36 North Platte River - Braided River, Nebraska
Use Ennis Quadrangle, Montana

Compare the stereo-aerial photograph with the braided stream of Ennis, Montana topographic map.

4. How do braided streams develop?

PLATE #34 Horseshoe Lake, Mississippi
Crowder Quadrangle, Mississippi

Compare the stereo-aerial photograph with the Crow
Compare the stereo-aerial photograph with the Crowder, Mississippi topographic map.

5. How do oxbow lakes form?

6. Why are two contour intervals used on the topographic map?

7. What are the brown chain of symbols along the Panola Quitman Floodway, i.e., what do the symbols represent?

PLATE #37 San Luis Valley, Colorado
Use Greenwood, Mississippi map

8. List one factor that helps to account for the intricate meanders on the stereo-aerial photograph.

Referring to the topographic map, notice the meander scars, flood plain, dissected plateau and the use of two contour intervals.

PLATE #35 Flathead Lake, Montana
Use West Delta, Louisiana map

9. How does a delta's distributaries compare with a river's tributaries?

10. Not all rivers form deltas when they enter large bodies of water. Why?

11. Referring to the topographic map, why are many channels so straight?

Topographic Map - Elk Point S.D., Neb., Iowa

12. Measure and record the width of the flood plain, dissected plateau and the use of two contour intervals.

13. What is the name of the landform on which Vermillion is located?

PART III

Ground Water - Karst Topography

PLATE #4 Sink Holes, Kentucky
Mammoth Cave Quadrangle, Kentucky

14. How did these sink holes form?

15. Referring to the topographic map, why does Little Sinking Creek disappear south-east Rocky Hill? (Southern part of the map).

16. What kind of a river is the Green River?

Take note of the numerous sink holes represented by contour depressions. The northern half of the map represents an area capped by sandstone and underlain by limestone, but on the southern half the sandstone has been eroded and the limestone is exposed.

Topographic Map Bowling Green, Kentucky

This map represents another example of an area partially capped by sandstone and underlain by limestone. Note the numerous sink holes and entrenched rivers. These areas are called Karst Topography.

PLATE #5 Haystacks, Puerto Rico

Read the summary and take note of another example of Karst Topography.

Topographic Map Interlachen, Florida

This map represents a Karst Topography in an area where the water table is very close to the surface. Thus the sink holes fill with water to form lakes. Again the entire area is underlain with limestone which dissolves readily in a warm humid climate. Would you like to live in a house in this area?

REFERENCES

1. Freeman Lab Sheets #220, #221 and #222

GEOLOGY I, LABORATORY ACTIVITY #12

Development of Landforms - Glaciers and Shore line

<u>Purpose</u>

To inquire into the following questions.

1. What landforms are associated with Alpine Glaciation, Continental Glaciation?

2. How were glacial landforms developed; what processes were involved?

3. How do glacial landforms appear on stereo-aerial photos and topographic maps?

4. What processes work to shape shorelines?

5. What landforms are associated with shorelines and how do they appear on topographic maps?

PART I

Color Slides of Landforms Associated With Alpine Glaciation

Your instructor will project several slides on the screen. Study each slide and take note of the features and how they were formed.

PART II

Stereo-Aerial Photographs and Topographic Maps Showing Landforms Associated With Alpine Glaciation

Study each photo and map, and read the summary at the bottom of each photo before attempting to answer the following questions.

PLATE #9 Carbon Glacier, Mt. Rainier National Park
Mt. Rainier National Park, Washington

The photo covers the area in the NW ¼ of the map, at the end of Carbon Glacier, north to Alice Falls, east to Cress Falls and Crescent Lake, south to Crescent Mts. and Elysian Fields, and west to Northern Craggs.

Locate the following features on both the photo and the topographic map: Cirque or Amphitheater, a saw-tooth ridge or arete matterhorn-like peak and a hanging valley.

1. Describe the river valley in terms of the slope of their walls and the valley floors. What is the Shape of the valleys?

2. Notice the two strings of small lakes just north-west of Mother Mountain. How were they formed?

3. Why is Mt. Rainier covered with glaciers today when the rest of North America is relatively free of glaciers?

PLATE #18 Longs Peak, Colorado
Rocky Mt. National Park, Colorado

Locate Longs Peak on the map; 40° 15' N, 105° 37' W.

4. How many cirques are cut into Longs Peak?

This map has numerous examples of glacial features. You should be able to start at a cirque and follow the old path of the glacier, identifying tarns, pater noster lakes, horns, aretes and U-shaped valleys.

5. The Continental Divide extends approximately from the northwest to the southeast portion of the map. What observation can you make concerning the direction of drainage on either side of the Continental Divide?

PLATE #14 Sue Lake, Montana
Chief Mountain, Montana

Examine the cirques, arete and stair steps in the photo. Locate Sue Lake on the map at 48° 51' N, 113° 50' 30" W.

6. What is the name of the glacial feature that is exemplified by Mt. Kipp, just south of Sue Lake?

Again, take note of the numerous glacial features and the Continental Divide.

PLATES #10 and #11

Study these plates in conjunction with the summary at the bottom of each plate. These are excellent examples of modern glaciers.

PLATE #16 Half Dome, California
Yosemite National Park, California

Study the photo and the local area on the topographic map, 37° 45' 30" N, 119° 32' W.

7. Record the change in elevation in the steepest portion of the following hanging valleys: Bridalveil Fall, 27° 43' N, 119° 39' W; Ribbon Fall 37° 44' N, 119° 39' W. Upper Yosemite Fall, 37° 45' N, 119° 35' 30" W.

8. Explain the origin of these hanging valleys.

PLATE #17 Walker Lake, California
Mono Craters, California

9. How did the lateral moraines (high, parallel ridges) form?

10. What glacial feature holds back the water of Walker Lake?

11. Locate Walker Lake on the map, 37° 53' N, 119° 9' W. Sketch a generalized pattern of contour lines that represent the lateral moraines.

Take note of the numerous glacial features on this map.

PART III

Stereo-Aerial Photographs and Topographic Maps Showing Landforms Associated with Continental Glaciation

PLATE #20 Drumlins, Wisconsin
Fond du Lac, Wisconsin

Draw a profile of a drumlin showing the steep end and the gentle sloping end, and indicate the direction in which the glacier advanced.

If north were at the top of the photograph, in what direction did the glacier advance?

12. According to the numerous drumlins on the map, in which direction did the glacier advance?

13. The flatness of the area of Fond du Lac and the ridge that extends along the east side of Lake Winnebago are related. Explain their origin.

PLATE #23 Turtle River, North Dakota
Larimore, North Dakota

14. What are the ridges in this photo?

15. What do the cities of Larimore and Fond du Lac (Map and Plate #20) have in common? What kind of material underlies the two cities?

PLATE #19 Knob and Kettle Topography
Refer to Kingston, Rhode Island Map

Compare the photograph with the section of the map along line 41° 24' N.

16. Was the shoreline irregular and is now being made straight or vice versa? Explain.

17. What do the star symbols (*) in Point Judith Bay and Matunuck Point signify?

PLATE #21

Optional: Interesting plate.

PART IV

Stereo-Aerial Photographs and Topographic Maps of Marine Coastlines

PLATE #29 Winter Harbor, Virginia
Mathews, Virginia

Locate this area on the map, 37° 24' N, 76° 15' W. Notice the distributaries.

18. What is the direction of the longshore currents?

19. What will eventually happen to Winter Harbor and the lagoon behind the barrier island?

PLATE #31 Saint Joseph Point, Florida
Compare with Provincetown, Mass. Map

20. Indicate the direction of the longshore currents in the photo and on the map along Wood End and Long Point.

21. Explain how Long Point will change in the future.

PLATE #75 Swan Pond, Massachusetts
Compare with Rehoboth, Delaware

Notice the path of sand in transport along the shore.

22. In general, where does sand for a beach originate?

23. What is the direction of the longshore current in the photo, on the map near Bethany Beach?

Try to imagine how the coastline appeared in the Pleistocene, see it now, and then imagine how it will be thousands or millions of years from now.

PLATE #28 Fraser Point, California
Compare with Mt. Tamalpais, California

24. How were the cliffs in this photo formed?

25. What is the name given to the rocks that are protruding above the water near the cliffs?

26. What part of the shoreline in the map is undergoing erosion, deposition?

27. How was the shoreline on the southeast side of Bolinas formed?

OPTIONAL: PLATES #76 - #83

APPENDIX D

A GEOLOGICAL PROBLEM

A geologist went into the area which is represented by our classroom model. He found that it was covered with a relatively heavy growth of summer vegetation which made outcrops difficult to locate and study. However, he was able to find numerous rock specimens in the mountains to the northeast and northwest part of the quadrangle and all of these were identified as gray granite.

At point "A", in the river bank, he found a section of sandstone resting on a conglomerate, which in turn rested on gray granite. The conglomerate was mainly composed of angular to subangular granite pebbles and boulders.

At the bottom of a gulley at point "B , he was able to identify a sandstone which matched the sandstone at point "A".

Since the outcrops were so scarce, he decided to walk along the edge of the river in hopes of taking rock specimens from the strata cut by the river. From point "A" to point "C" he found several outcrops of sandstone, but at point "C" he found that the sandstone was overlain by shale which dipped 9° toward the south.

Restricting himself to the course of the river, he found shale at points D, E, and F. At point "G" he found that the shale was overlain by a cherty limestone which formed the entire length of the ridge which ran in an east-west direction. He measured the strike and dip at point "G" to be N. 90° E. (strike) and 11° S. (dip).

At point "H" he found that the cherty limestone was overlain by a shale which resembled the shale north of the east-west trending ridge and again he measured strike and dip and found that they were the same as at point "G", N. 90° E. and 11° S.

On the basis of the above information, and with the aid of the topographic map, complete the following assignment.

1. What is the height of the mountain to the northeast? The height of the east-west trending ridge?

2. Using light colored pencils, superimpose a geologic map on your topographic map and indicate strike and dip with symbols.

3. Explain (what is and why) the relationship of the rock types to the topographic expression.

4. In what type of climate would one expect to find this quadrangle?

5. Draw a north-south cross-section of the quadrangle.

6. Which rocks are the oldest? Youngest? How can a geologist determine this?

7. Piece together the geologic history of this quadrangle.

8. How many square miles are represented by the topographic map?

9. Why does the river tend to parallel the limestone ridge?

PROBLEM 2, SUMMARY OF FIELD NOTES

1. Rock "B" in contact with rock "A", strike is estimated to be N 5 E, dip unknown. Rock "B" is west of rock "A".

2. Rock "B" is in contact with rock "C" to the west, strike and dip unknown.

3. Rock "C" is overlain by and in contact with rock "D"; strike N 15 W, dip 35 NE.

4. Rock "B" overlain by rock "C"; strike N 90 E, dip 25 N.

5. Rock "C" overlain by rock "D"; strike N-S, dip 35 W.

6. Rock "B" overlain by rock "C"; strike N 5 E, dip 40 NNW.

7. Rock "C" overlain by rock "D"; strike N 15 W, dip 45 NE.

8. Rock "C" overlain by rock "D"; strike N 20 W, dip 45 NE.

9. Rock "B" in contact with rock "C" to the north; strike & dip obscured.

10. Rock "C" overlain by rock "D"; strike N 45 E, dip 45 NW.

11. Rock "B" overlain by rock "C"; strike N 10 E, dip 50 NW.

12. Rock "A" in contact with rock "B" to the north; no strike or dip.

13. Rock "B" in contact with rock "D"; no strike or dip.

14. Rock "A" in contact with rock "B" to the east.

Note: Rock "A" was dated as the oldest, and rock "D" the youngest.

---

1. Properly place strike and dip symbols at all outcrops, indicate amount of dip.

2. Sketch the contact lines between rock types and color the areas to indicate the distribution of each rock type.

Answer the following questions on a separate piece of paper.

3. List the structural features that you can detect.

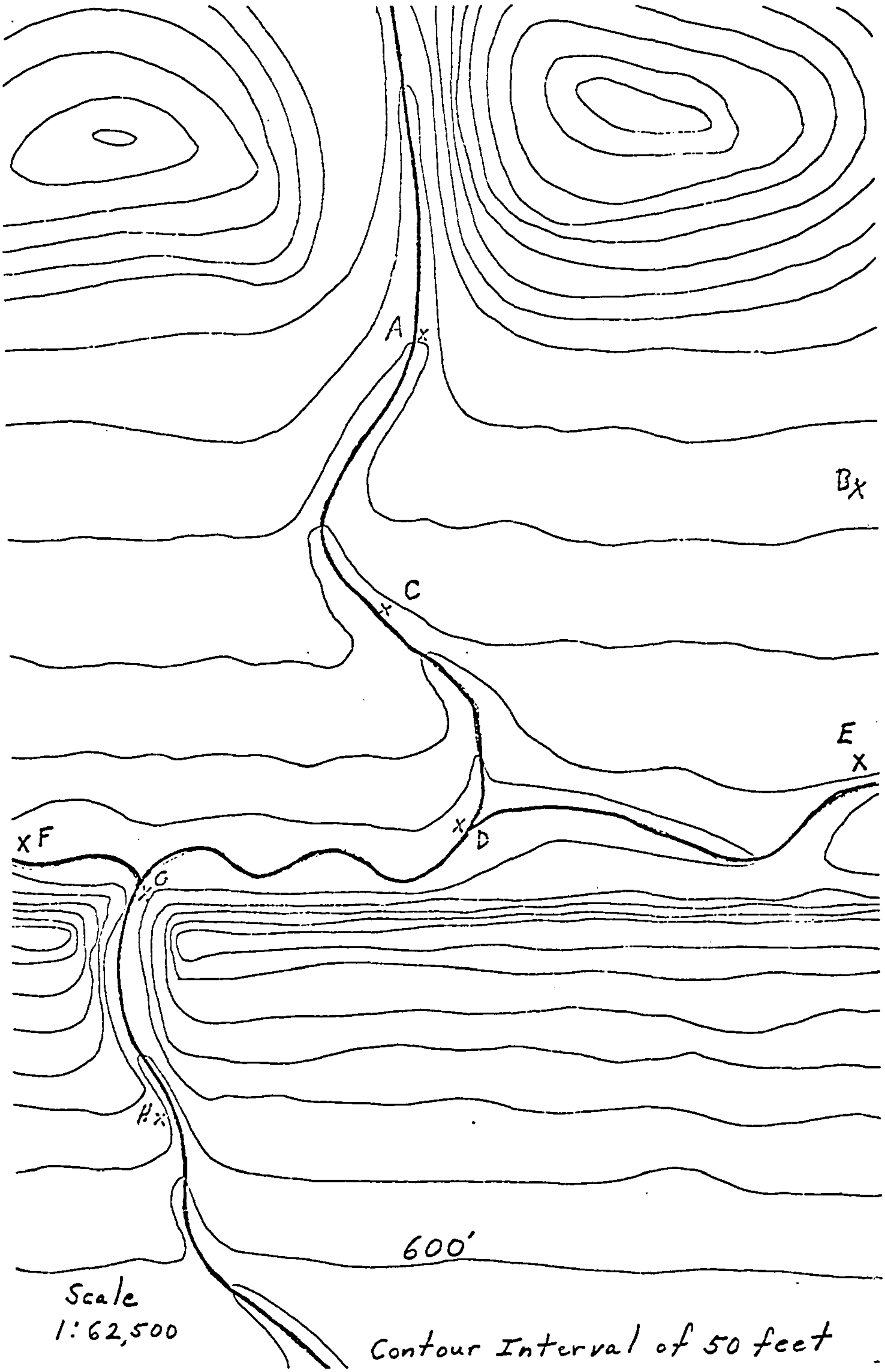
4. Draw a cross-section of the major structure, using dashed lines to indicate eroded beds.

5. Relate the rock types to the topographic expression.

6. Could these types of structural patterns and related topographic features actually occur in nature? Please explain.

7. List the rocks in order of age, starting with the oldest one.

8. Starting with the deposition of the rocks in a horizontal position, list the historical events that produced the present structural pattern and related topographic features.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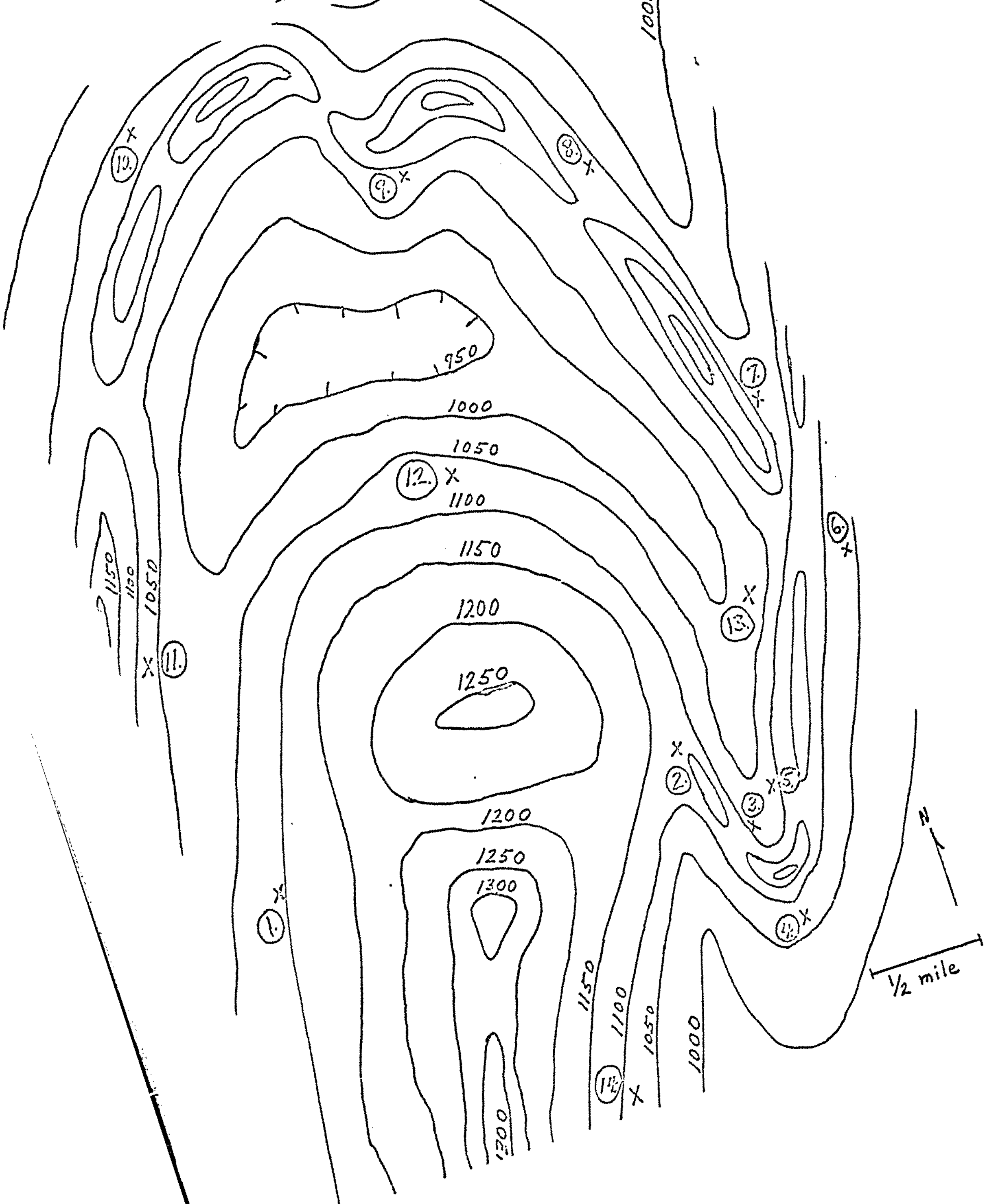
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APPENDIX E

ACHIEVEMENT TEST IN GEOLOGY CONTENT

DIRECTIONS:

Indicate your name and the number of your test booklet on your answer sheet.

This test is made up of different kinds of questions, each one of which has several possible answers. Choose the best answer for each question. After the number on the answer sheet corresponding to the question you are answering, blacken the one lettered space that agrees with your choice of the possible answers. Be careful to blacken the lettered space that corresponds to the answer you have chosen. Answer all of the questions.

PLEASE DO NOT MARK IN THIS BOOKLET. THANK YOU.

* The starred (*) questions were not scored when collecting the data on student achievement in geology content.

DIRECTIONS: For all items, choose the one best answer or completion.

Questions 1 through 9 refer to MAP - I

1. The Frankstown Branch Juniata River, west of McKee Gap, is

A. an entrenched river
B. flowing northward
C. in the stage of old age
D. a braided river
E. in the stage of early youth

2. The contour interval on this map is

A. 10 feet
B. 20 feet
C. 40 feet
D. 50 feet
E. 100 feet

3. The only bench mark on the map is located at

A. McKee Gap
B. Hollidaysburg
C. Duncansville
D. Martinsburg
E. Roaring Spring

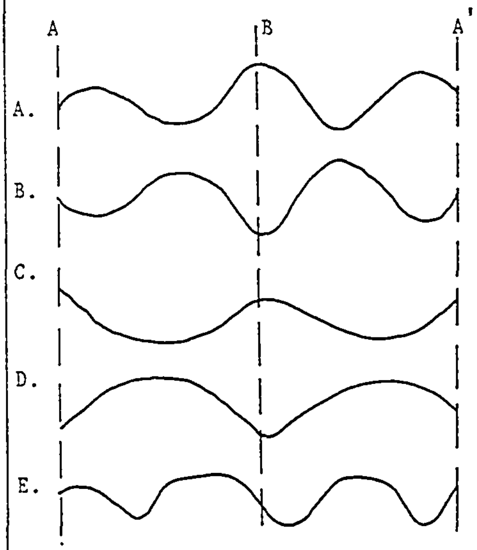
4. McKee Gap is

A. a water gap
B. a stop gap
C. an eroded river terrace
D. a wind gap
E. an eroded lateral moraine

5.* The strike and dip at B is N 10 W, 35 S.W., the cross-section along line A-B-A', west to east is

A. an anticline-syncline
B. a syncline-anticline-syncline-anticline-syncline
C. an anticline-syncline-anticline-syncline-anticline
D. A syncline-anticline
E. an anticline-syncline-anticline

6. A simple topographic profile along line A-B-A' would appear as



7. The distance along line A-B-A' is

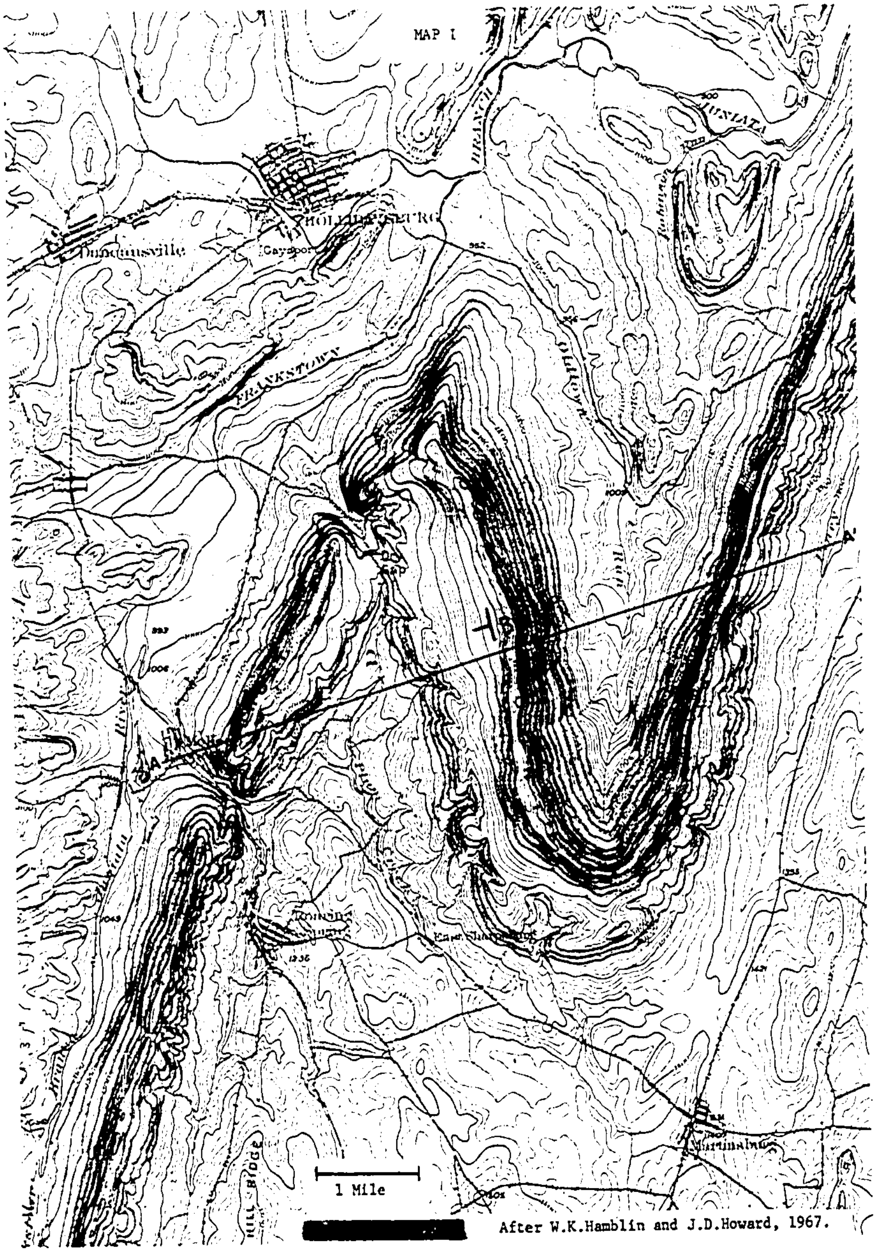
A. seven miles
B. six miles
C. closer to ten miles
D. less than two miles, but more than one mile
E. not enough information given

8.* The U-shaped ridge formed by Short Mountain and Loop Mountain is

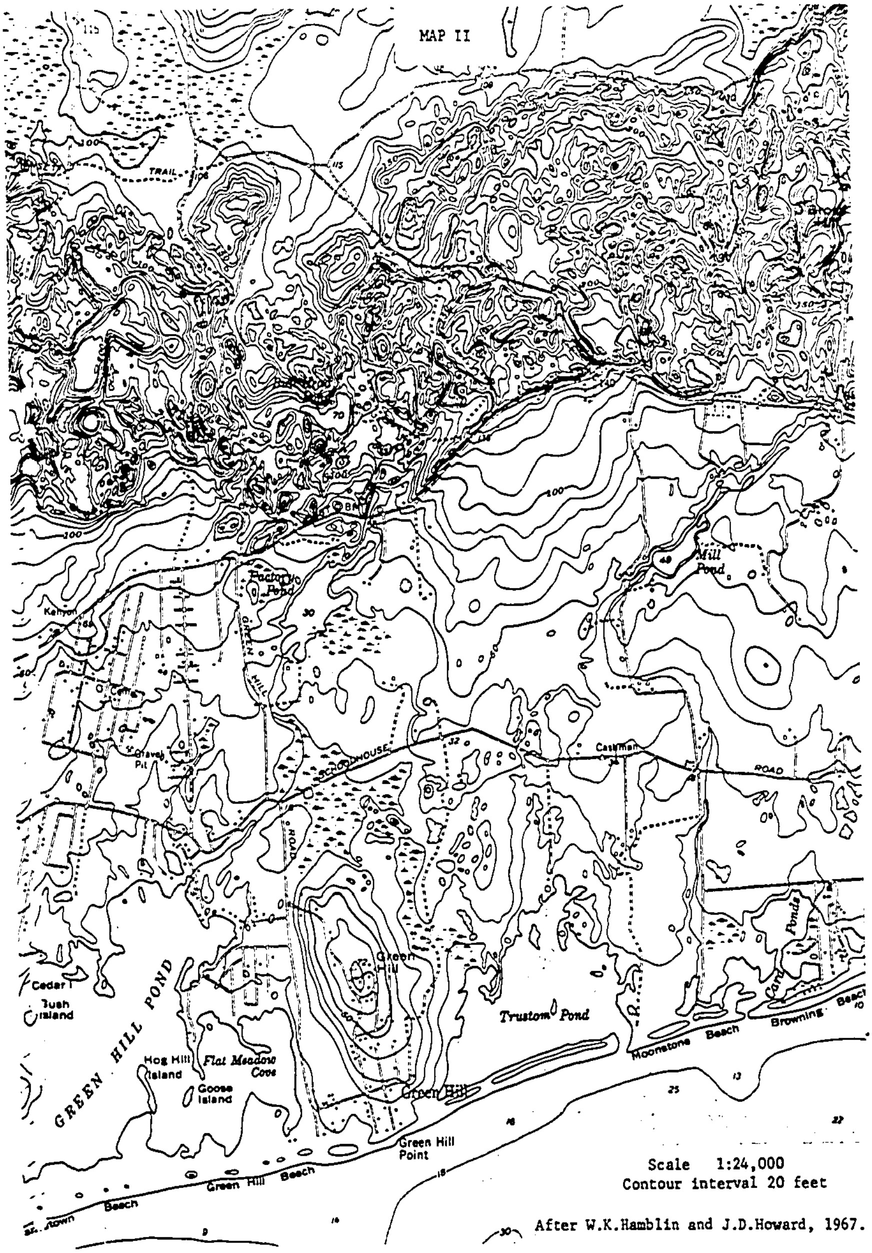
A. a N. N.E. plunging eroded syncline
B. a S.S.W. plunging eroded syncline
C. a N.N.E. plunging eroded anticline
D. a S.S.W. plunging eroded anticline
E. a N.N.E. nonplunging fold

9. Which of the following is a true statement?

A. the rocks of Short Mountain are more resistant than the rocks of Loop Mountain



[redacted] After W.K.Hamblin and J.D.Howard, 1967.



Scale 1:24,000
Contour interval 20 feet

After W.K.Hamblin and J.D.Howard, 1967.

B. the rocks of Loop Mountain are older than those of Short Mountain
C. the rocks along Oldtown Run are more resistant than the rocks along Loop Mountain
D. the rocks along Plum Creek are younger than the rocks along Oldtown Run
E. a valley glacier once occupied the area along Oldtown Run

Questions 10 through 14 refer to MAP - II

10.* Most of the upper one third of the map is

A. a dissected plateau
B. a terminal or end moraine
C. a raised beach
D. a drumlin field
E. a gravel bar

11.* The lower half of the map represents

A. a shoreline of submergence
B. an outwash plain
C. a ground moraine
D. a flood plain
E. a tidal flat

12.* Bull Head Pond is most likely a(n)

A. kettle filled with water
B. pothole filled with water
C. area of subsidence filled with water
D. sinkhole filled with water
E. result of a dammed river

13. Trustom Pond is

A. an area of erosion by seaward currents
B. an area of subsidence
C. growing larger
D. being filled with sediment
E. a tarn

14. In general the shoreline is

A. submerging
B. being eroded
C. straightened by longshore currents
D. bordered by wave-cut cliffs
E. being made more irregular

Questions 15 through 19 refer to MAP-III

15* The isolated high topography just west of Crooked Creek (#1) is a(n)

A. monadnock
B. volcanic neck
C. meander core
D. oxbow
E. area of uplift

16.* Dark Hallow quarry, in the N.E. corner, is a

A. limestone quarry
B. granite quarry
C. gravel quarry
D. slate quarry
E. glass sand quarry

17. The area represented on the map is probably located in a(n)

A. semi-arid climate
B. frigid climate
C. arid climate
D. humid climate
E. could be any of the above

18.* The White River is

A. in a youthful stage
B. in a U-shaped valley
C. flows from west to east
D. an entrenched river
E. a braided river

19. Most of the area represented by this map is

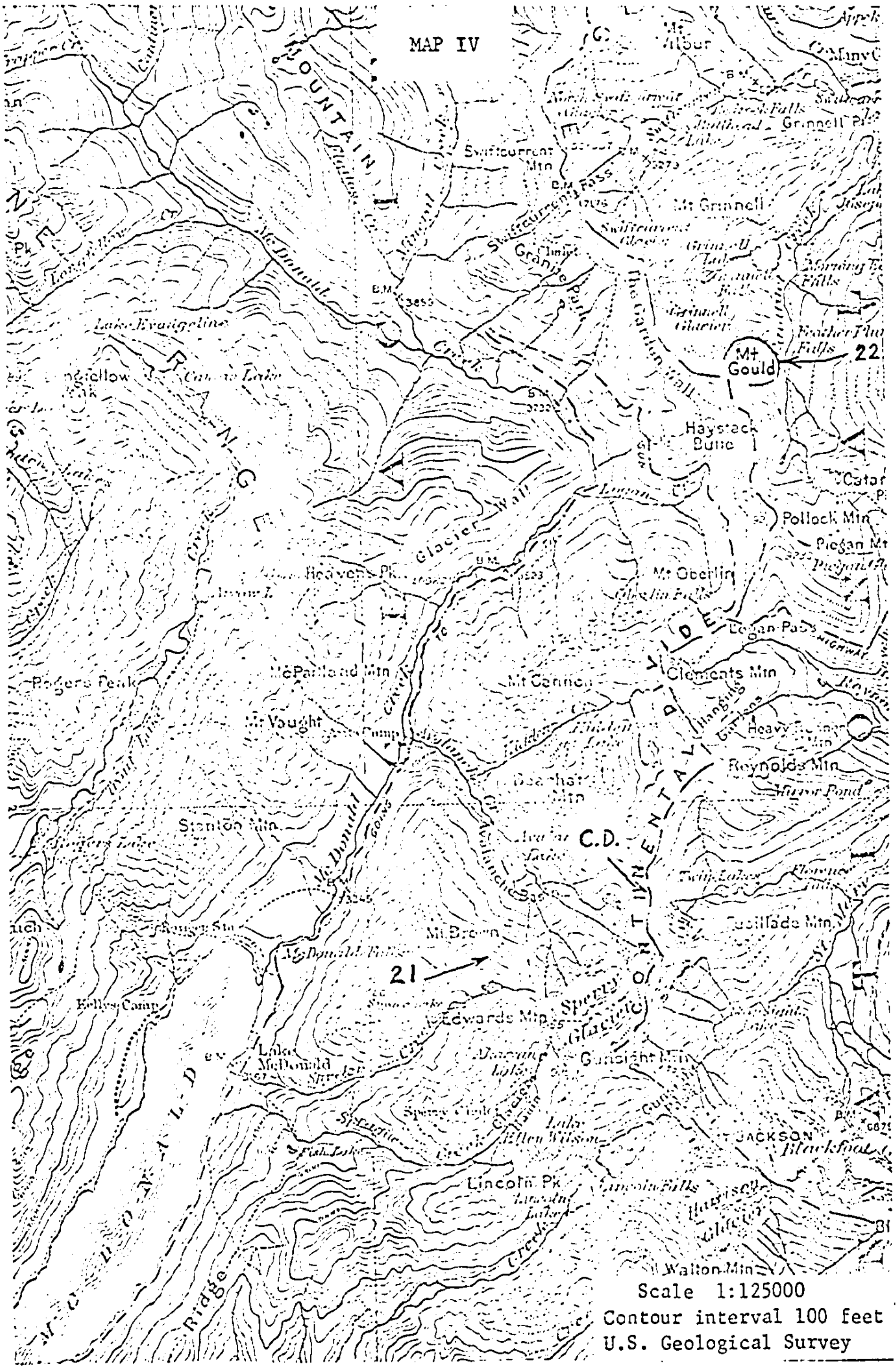
A. a mesa
B. Karst topography
C. in a youthful stage
D. in the kettle stage
E. in the pothole stage

Questions 20 through 25 refer to MAP-IV

MAP III

Scale 1:62,500
Contour interval 20 feet

After W.K.Hamblin and J.D. Howard, 1967.


MAP IV
Swiftcurrent Mtn
Mt Grinnell
Grinnell Glacier
Mt Gould
22
Haystack Butte
Pollock Mtn
Piegan Mt
Mt Oberlin
Logan Pass
Clements Mtn
Heavy Runner Mtn
Reynolds Mtn
Mt Cannon
Heavens Pk
McPartland Mtn
Mt Vaught
Rogers Peak
Stanton Mtn
Lake Evangeline
Longfellow Pk
C.D.
Mt Brown
21
Edwards Mtn
Sperry Glacier
Gunsight Mtn
Lake McDonald
Lincoln Pk
Walton Mtn
Garden Wall
Glacier Wall
Mirror Pond
Twin Lakes
Fusillade Mtn
Jackson
Blackfoot
Harrison Glacier
Lake Ellen Wilson
Kelly's Camp
Scale 1:125000
Contour interval 100 feet
U.S. Geological Survey

20. McDonald Creek, just north of Lake McDonald, is

A. in a cirque
B. in a U-shaped valley
C. an intermittent stream
D. flowing northeastward
E. is in the stage of old age

21. The Continental Divide, marked C.D., is a(n)

A. cuesta
B. matterhorn (or horn)
C. cirque
D. arete
E. a hogback

22.* The number 21 on the map marks a(n)

A. arete
B. matterhorn (or horn)
C. sinkhole
D. cirque
E. lateral moraine

23.* Mount Gould, number 22, is a

A. monadnock
B. cirque
C. matterhorn (or horn)
D. kame
E. butte

24.* The area represented by this map is about

A. 4 sq. miles
B. 440 sq. miles
C. 200 sq. miles
D. 336 sq. miles
E. 150 sq. miles

25. If the above map were drawn to a larger scale

A. the present size map would be capable of representing a larger area
B. the number of inches measured between any two points on the map would remain the same
C. the true distance between any two points would increase
D. a larger map would be necessary to represent the same area
E. a graphic scale would be the same for both maps

26.* An aerial photograph containing three (3) scales is reduced by ½ its size. In regard to the reduced photo

A. the verbal scale is still correct
B. the fractional scale is still correct
C. both the verbal and the fractional scales are still correct
D. the graphic scale is still correct
E. both the graphic and the verbal scales are still correct

27. The Norman area can <u>most</u> accurately be contoured by using a contour interval of

A. 5 feet
B. 10 feet
C. 20 feet
D. 40 feet
E. 100 feet

28. When hiking in an unfamiliar area, the most helpful aid would be a

A. geologic map
B. cross-section of the area
C. knowledge that all rivers generally south
D. profile of a footpath in the area
E. topographic map fo the area

29.# Minerals are important to the geologist because minerals

A. have aesthetic value
B. display cleavage
C. have special optical properties
D. give clues to the origin of rocks
E. are composed of rocks

30. Material for sedimentary rocks come from the

A. weathering of igneous, metamorphic and sedimentary rocks
B. remelting of igneous rocks

C. decomposition of igneous and metamorphic rocks
D. depositional basins on the ocean floor
E. extrusive rocks of volcanoes

31.* A normal fault is generally believed to be the result of primarily

A. tensional (decompressional) forces acting in and on the earth's crust
B. excessive erosion of the continent
C. atmospheric pressure
D. compressional forces acting in or on the earth's crust
E. extensive lava flows

32. All unconformities are characterized by a(n)

A. angular contact between beds
B. period of erosion or non-deposition
C. smooth horizontal contact between beds
D. obviously visible irregular contact between beds
E. ripple marks along the contact between beds

33.* All landforms are a result of

A. structure of the rock formations
B. nature of the rocks
C. climatic conditions
D. a long period of time
E. all of the above

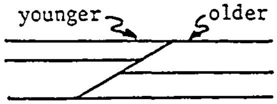
34. An entire area of several hundred square miles of horizontal sedimentary rock strata is gradually uplifted and eroded by the processes in a semi-arid climate. The dominant landform(s) will be

A. inselbergs (island mountains)
B. rounded hills and ridges
C. hogbacks and cuestas capped by resistant rocks
D. cone-shaped hills on resistant rocks
E. mesas and buttes capped with resistant rocks

35.* The formation of landforms is influenced most by

A. soil creep in both arid and humid climates
B. wind in the arid regions and sheet wash in humid regions
C. freezing and thawing in an arid region
D. the vegetation of the region
E. running water in both arid and humid regions

36. A cross-section of faulted horizontal sedimentary strata after erosion. The fault is

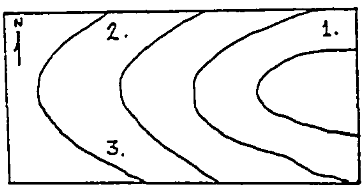


A. a thrust fault
B. a normal fault
C. a strike slip fault
D. could be all of the above
E. not enough information given

37. One should be most cautious about building a house on

A. a mesa
B. shale in a semi-arid region
C. sandstone underlain by limestone in an arid region
D. limestone in a humid region
E. glacial till

38. Which of the following statements in reference to the map view are true?



A. is the strike and dip at point one (1) were N 60 E, 35 SSE, it must be a plunging anticline
B. if the strike and dip at point two (2) were N 45 E, 35 NW, it must be a plunging syncline

C. if the rock at point one (1) is older than the rock at point two (2) or three (3), it must be a plunging syncline
D. if the rocks between point one (1) and point two (2) are older than the rocks at point one (1), but younger than the rocks at point two (2), it must be a plunging syncline
E. none of the above are correct

39. Contour lines

A. are always found on geologic maps
B. never touch each other
C. enclose upon themselves or extend off the map
D. connect point of unequal elevation
E. all of the above are correct

40. A volcanic lava flow that spreads rather rapidly over an extensive area of gentle slope is probably

A. a rhyolitic lava
B. low in the amount of silica it contains
C. low in amount of water it contains
D. forming an extensive dike
E. accompanied by frequent explosions

41.* In the identification of minerals a first approximation will make use of

A. crystal lattice and axes
B. cleavage, hardness and color
C. x-ray diffraction patterns
D. optical properties
E. basic chemistry

42. The naming of the three broad categories for the classification of all rocks--igneous, metamorphic and sedimentary--results from a consideration of

A. mineral composition
B. texture
C. optical properties
D. present location
E. origin

43.* The composition and texture of sedimentary rocks provide information concerning

A. the relative distance of transportation
B. the method of transportation
C. the types of rocks in the source area
D. depositional environment
E. all of the above are correct

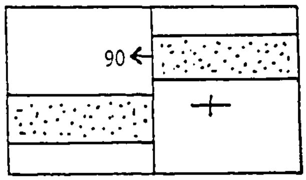
44. According to a <u>strict</u> definition, a mineral is

A. chemically organic
B. fixed in chemical composition
C. composed of carbon compounds
D. noncrystalline
E. none of the above

45. The best map to use when attempting to find the age of the rock in your locality is a

A. tectonic map
B. geologic map
C. physiographic province map
D. topographic map
E. planimetric map

46. The following figure is a



A. map view of a normal fault
B. cross-section of a thrust fault
C. map view of a thrust fault
D. monadnocks
E. a horst and graben

48. Several layers of sedimentary rock strata have been domed-up. The younger strata are generally more resistant than the older strata. After a long period of erosion

A. the interior of the dome will be a topographic basin
B. the more resistant rock will form topographic lows
C. the younger rocks will have weathered quicker than the older rocks
D. a map view will show older rocks around the edge of the eroded dome
E. the more resistant rocks will be found toward the center of the eroded dome

49. Assuming that the necessary atoms are present, most minerals will form on or in the earth

A. only in certain environmental conditions
B. in almost any environment
C. at temperatures above 2000°C
D. at pressures less than one atmosphere
E. all of the above are correct

50. Obsidian will usually be produced by

A. slow cooling below the surface of the earth
B. rapid cooling above or at the surface of the earth
C. gradual cooling at the surface of the earth
D. high heat and pressure of overlying sediments
E. magmatic stoping

51. Perfect cleavage of minerals occurs

A. along planes of weakly bonded atoms
B. along rows of electrons
C. between two planes of strongly bonded atoms
D. perpendicular to the strike
E. in all minerals

52.* In his attempt to explain how the present condition of a part of the earth's crust came about, a geologist may rely on

A. unconformities
B. faults
C. folds
D. uplift
E. all of the above

53.* A concluding statement made by a geologist after careful study of a field problem

A. should be considered as fact
B. will meet with the approval of all other geologists
C. should be considered as one interpretation
D. is not subject to change
E. will always be correct if his methods were scientific

54.* The most effective process at work to shape the surface of the continents is

A. glaciation
B. running water
C. wind
D. ocean currents
E. turbidity currents

55.* The texture of igneous rocks is directly related to their

A. cooling history and chemical composition
B. present location at the surface of the earth
C. source of sediments
D. chemical composition of parent magma and arrangement of crystals
E. crystal sizes and shapes

56. Which of the following does not influence the rate of weathering of a sedimentary rock

A. type and degree of cementation
B. degree of lithification
C. permeability of the rock
D. agent which transported the sediments
E. chemical composition

57.* The most abundant rock forming minerals are

A. carbonates
B. silicates
C. sulfates
D. calcarenites
E. amphiboles

58. Lithified gravel and sand is a

A. metamorphic rock
B. form of shale
C. prophyritic rock
D. fine-grained sandstone
E. conglomerate

59. Cross-bedding is generally associated with

A. sandstone
B. shale
C. limestone
D. basalt
E. mica schist

60. A sheet-like body of basalt is overlain and underlain by sedimentary rock

A. it is a lava flow if it has tiny intrustions into the overlying formation
B. it is a lava flow if it is not weathered on the upper contact
C. it is a dike
D. it is a sill if it has slightly intruded the overlying formation
E. it is a volcanic stock

61. In the analysis of a problem involving the structural changes in sedimentary rock strata, the one point that is generally assumed to apply is

A. that subsudence took place
B. that folding and faulting played a part
C. the concept of original horizontality
D. that folded beds are usually overturned
E. the concept of cross-bedding

62. The best evidence to support the direction in which a former ice-sheet moved are

A. cirques
B. lateral moraines
C. kames
D. kettles
E. drumlins

Questions 63 through 65 refer to the following passage.

Whether a stream erodes its bed, deposits sediment on it, or does neither depends on a balance among water volume, sediment load, slope and shape of the stream bed, and other factors. If a stream is in balance between long-term erosion and deposition, and if a change in one of the controlling factors occurs, sometimes the details of shape of the stream beds (bends, sand bars, etc.) will change to maintain the condition of balance (or "grade"). But if the disturbance is too drastic, the balance may be upset and the stream may begin a phase of erosion or deposition on its bed. For example, when a big dam and reservoir are built on a major stream (such as Hoover Dam on the Colorado River), most of the stream sediment settles out in the reservoir, and relatively clear water goes out the spillway. This water, without a load of sediment to carry below the dam, can erode the bed. If such erosion is not anticipated in the design of the dam, it might undermine the toe of the dam and cause damage.

63.* The best title for the above paragraph is

A. Stream Grade
B. The Formation of Bends and Sand Bars
C. Problems of Design with the Hoover Dam
D. Stream Erosion
E. Increased Stream Load and Erosion

64. According to the author

A. erosion is a factor that need not be considered in the design of a dam
B. stream load and the profile of the stream-bed do not influence the erosion or deposition of sediment
C. streams do not undergo change over a long period of geologic time
D. the construction of a dam will affect the grade of a river
E. once a stream has established equilibrium with its surroundings, it will remain unchanged forever.

65. The mechanism of stream dynamics supports the idea that

A. increased rainfall will result in increased deposition of sediments
B. increase in sea level, into which the river flows, will produce an increase in stream erosion
C. tilting of the continent toward the mouth of the river will produce increased headward erosion
D. reduction in the amount of stream flow will increase erosion and incise a deep, narrow channel
E. increase in the amount of sediments from a river's drainage basin will produce increased erosion in the main river trunk

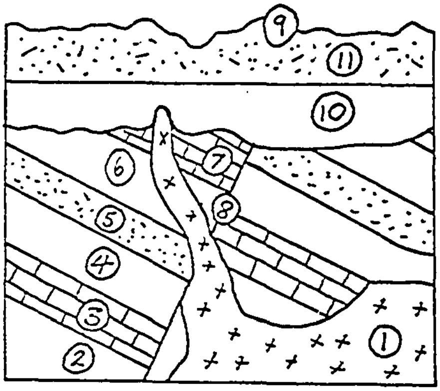
---

66. Undisturbed sedimentary strata on older underlying sedimentary strata supports the

A. concept of contact metamorphism
B. law of superposition
C. concept of uplift and tilt
D. law of multiple hypotheses
E. concept of sandwiched beds

67.

Cross-section



The correct sequence of events is

A. 2--3--4--5--6--7--tilt--normal fault(8)--erosion--10--1--11 (or 11--1)--erosion (9)
B. 7--6--5--4--3--2--thrust fault(8)--deposition--erosion--10--1--11 (or 11--1)--erosion
C. 1--2--3--4--5--6--7--tilt--normal fault (8)--erosion--10--11--erosion (9)
D. 2--3--4--5--6--7--tilt-- thrust fault(8)--10--1--11 (or 11--1)--erosion(9)
E. 7--6--5--4--3--2--overturn--thrust fault(8)--1--10--11--erosion(9)

Questions 68 through 70 refer to the following passage

The Precambrian rocks of the Adirondacks probably represent a much longer period of earth history than do the rocks exposed in the lowlands. They record many events of sedimentation, metamorphism, igneous intrusion, folding, faulting, and mountain building. These events were followed by a long period of erosion, about 600 million years ago, which produced the relatively flat surface on which the younger sedimentary rocks, consisting of limestone, dolomite, sandstone, and shale, were laid down. These early Paleozoic rocks, about 525 million to about 440 million years old, generally underlie the lowlands, such as those north of Ticonderoga, and are also found in the downfaulted valleys in the Adirondack province.

The major topographic features of the area are the fault-controlled mountains and valleys east of the main body of the Adirondacks. The scarps are fault-line scarps, produced by differential erosion along old fault lines. The downdropped blocks are mostly floored by the softer Paleozoic rocks; the mountains are of igneous or metamorphic rocks.

68. The best title for the above passage is

A. Downfaulting in the Adirondack Province
B. Topography of the Adirondacks
C. Precambrian Rocks of the Adirondack Mountains
D. History of Sedimentary Rocks in the Adirondacks
E. Geology of the Adirondack Mountains

69. According to the author

A. the area was probably underwater about 600 million years ago
B. older rocks were laid down on the Paleozoic rocks
C. erosion was uniform over most of the area
D. the topography reflects earlier faulting
E. surface features are mainly the result of folded sedimentary rocks

70. If one were to inspect several different maps (tectonic, topographic, geologic, etc.) of the area described, he would expect to find that

A. the location of the youngest rocks coincide with the valleys
B. sedimentary rocks dominate the highest elevations
C. the youngest rocks cropout in the mountains
D. all of the Precambrian rocks are igneous or metamorphic
E. unconformities do not exist in this area

71.* A peneplain is to a pediment as a

A. mesa is to a butte
B. longshore current is to a stream
C. monadnock is to an inselbert (island mountain)
D. barrier beach is to a baymouth bar
E. hogback is to a cuesta

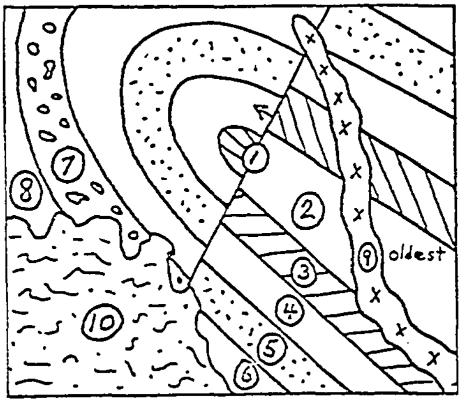
72. A dentritic drainage pattern would most likely develop on

A. a domed mountain
B. highly jointed igneous rocks
C. folded sedimentary rocks
D. on the flanks of a volcanic cone
E. flat-lying sedimentary rocks

73. In a region that is youthful with respect to the cycle of stream erosion, one might expect to find

A. broad flat areas at stream level and low rounded inter-stream dividers
B. undissected flat areas atop most interstream dividers
C. highly integrated drainage and no undrained flat surfaces at any level
D. more sloping surface than in maturely dissected region
E. meanders and oxbow lakes

74. The correct sequence of events is



Map View

A. normal fault (1)--2--3--4--5--6--7--8--9--anticlinal folding--erosion--10--erosion
B. 9--2--3--4--5--6--10--7--8--thrust fault (1)--synclinal folding--erosion--9--10(or 10--9)--erosion
C. 2--3--4--5--6--7--8--uplift--anticlinal folding--erosion--normal fault(1)--erosion--9--10(or 10--9)--erosion
D. 10--8--7--6--5--4--3--2--thrust fault (1)--uplift--erosion--9--folding--erosion
E. 2--3--4--5--6--anticlinal folding-erosion--normal fault (1)--erosion--7--8--9--10 (or 10--9)--erosion

75. A V-shaped valley incised into the floor of a broad floodplain is evidence of

A. the work of a valley glacier
B. recent uplift of the land
C. a change of climate from humid to arid
D. a rising base level
E. an increase in bed load

Questions 76 through 81 refer to MAP V

76. The landforms labeled A are

A. hogbacks
B. bajadas
C. inselbergs (island mountains)
D. alluvial fans
E. playas

77.* The bedrock surface along line D is a

A. fault
B. pediment
C. sandy beach
D. cuesta
E. playa

78. The area along line E in the upper righthand quarter of the map is

A. a playa
B. coastal plain
C. bajada
D. pediment
E. inselbert (island mountain)

79.* The landform labeled C is a(n)

A. alluvial fan
B. cuesta
C. playa
D. delta
E. monadnock

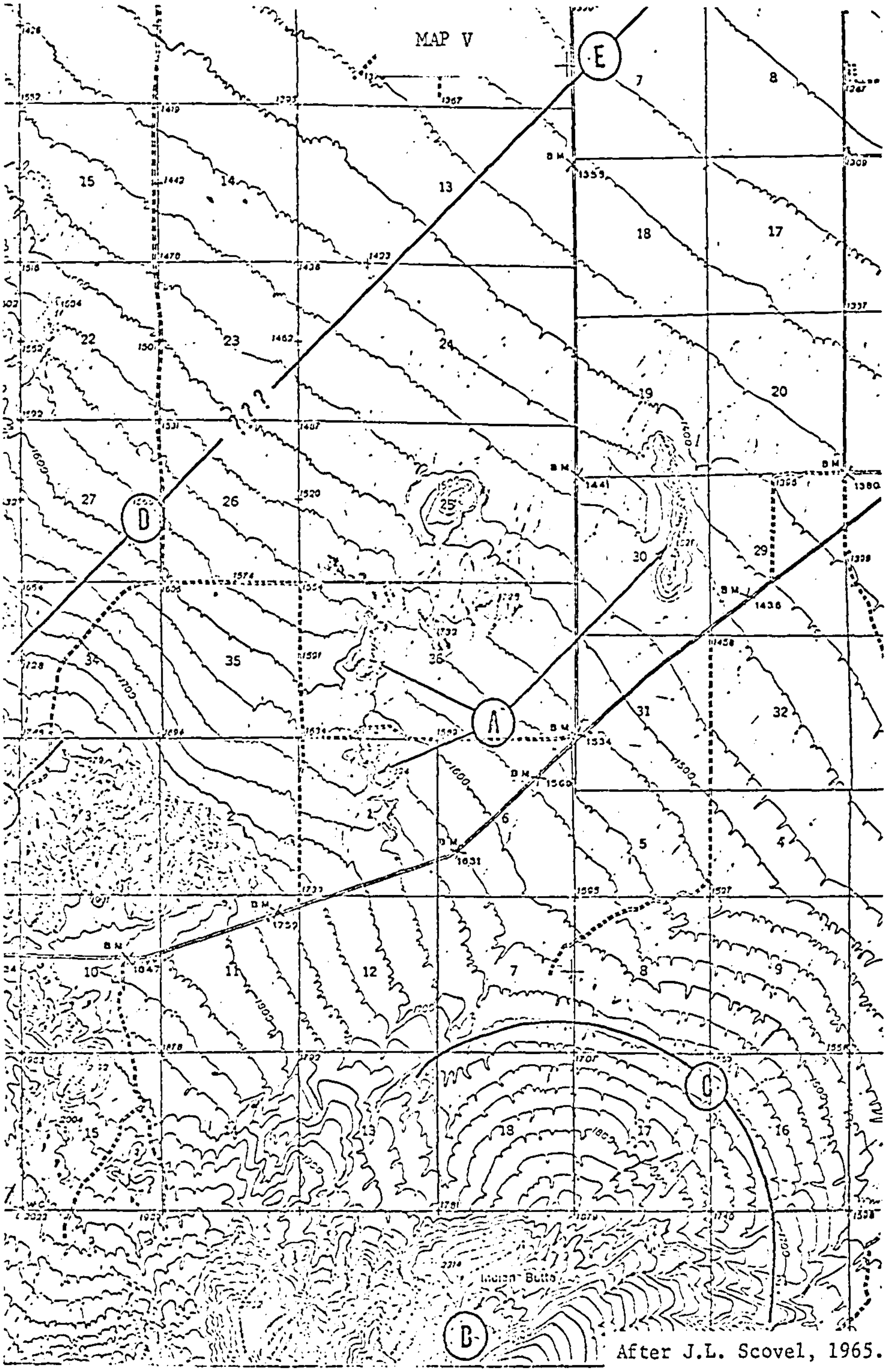
80. If one continued off the upper righthand corner of the map in a NE direction, he would come to a(n)

A. alluvial fan
B. playa
C. pediment
D. bajada
E. ocean

81.* If this line is one inch long (————————), what is the scale of this map?

A. 1 inch = 3 miles
B. 1 inch = about 4 miles
C. 1 inch = 1 mile
D. 1 inch = 6 miles
E. not enough information given

82.* A waterfall flowing into a U-shaped valley probably formed because



After J.L. Scovel, 1965.

A. ice sheets are good agents of erosion
B. valley glaciers tend to straighten valleys
C. the ability of glaciers to erode depends on the thickness of the ice
D. the glacier encountered an exceptionally resistant mass of rock
E. the river was dammed by a terminal moraine

83. Several caverns have been discovered by

A. studying kame terraces
B. exploring kettles
C. accidentally falling into potholes
D. seismological studies
E. exploring sinkholes

84. Norman, Oklahoma is located in

A. north latitude and south longitude
B. south latitude and west longitude
C. east latitude and north longitude
D. west latitude and north longitude
E. north latitude and west longitude

Questions 85 through 87 refer to the following passage

Minerals and other raw materials are not distributed equally over the earth. Neither do they occur in a continuous spectrum of grades that makes their availability a simple function of energy input, economics, or technology--powerful though such factors are. In spite of all that can be achieved with sufficient application of power, intellect, and population control, the world and its resources are finite and thus eventually impose limits both on population and on rates of consumption. The resources of the sea may well prove to be large, but they are at present not known in detail, are almost certainly overestimated by advocated, and will require much effort and ingenuity to exploit. Extraterrestrial resources for earthly use exist only in science fiction.

The concept of unlimited mineral resources denies the restraints and belittles the difficulties. It is based on five main premises, none of which can be taken without reservation, and some of which are less supportable than others. Wide uncritical acceptance of these soothing premises contributes to a dangerous complacency toward problems that call not only for intensive, wide-ranging, and persistent scientific and engineering investigation, but also for new social patterns and wise legislation.

85.* The best title for the above passage is

A. Wealth of Raw Materials in the Earth's Crust
B. Realities of Mineral Distribution
C. Unlimited Mineral Resources
D. World Resources and Population Control
E. Five Premises in Support of Wise Use of Mineral Resources

86.* The author <u>implies</u> that

A. man takes raw materials from areas of concentration and scatters them through consumption
B. extraterrestrial resources may become a reality soon
C. more good can be accomplished through use of power, intellect, and population control
D. man has barely begun to reduce the supply of raw materials
E. the oceans are virtually untapped sources of raw materials that may exceed all expectations

87. The author is calling attention to the

A. problem of present mineral shortages
B. unequal distribution of raw materials
C. misunderstandings that influence the present policy toward consumption of raw materials
D. need to locate new sources of raw materials

E. relationships that exist between social patterns, technology, research, government and raw materials

88. A sample of sedimentary rock composed of well cemented, highly angular, coarse fragments of varying size, shape, and composition indicates that the

A. rock will weather rapidly in a humid climate
B. cementing material must be calcium carbonate
C. sediments were transported and redeposited several times before lithification
D. source area was relatively close-by
E. sediments came from a weathered rhyolite

89. A rock composed of tightly interlocked coarse crystals suggests that the rock

A. is a well cemented conglomerate
B. was deposited in relatively shallow water
C. was formed from fragments that were transported a great distance by swiftly flowing water
D. was formed well below the earth's surface
E. formed when lava came in contact with a large body of water

90.* A river may terminate or disappear on a topographic map when

A. the area is very sandy and gravely
B. the underlying rock is limestone
C. the region is covered with a highly jointed lava
D. all of the above are correct
E. only A and C are correct

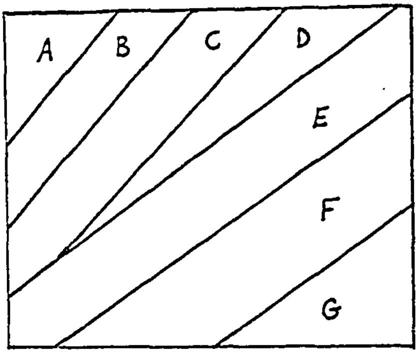
91.* The rock immediately above an unconformity will always show on a geologic map

A. in contact with more than one older rock
B. to the west of the younger rock
C. as a different rock type or formation
D. up dip from the other beds
E. none of the above

92. An angular unconformity would result from the following recorded sequence in the rocks

A. deposition--deformation--erosion--deposition
B. deformation--deposition--erosion--deposition
C. deposition--deformation--deposition--erosion
D. deposition--erosion--deposition--deformation
E. deformation--deposition--erosion--deformation

93.*



Map View 1 inch = 50 miles

Formation D on the above map has a wedged shape outcrop due to the influence of

A. irregular erosion
B. topographic distortion
C. a very young river
D. an unconformity
E. folding

94. If formation A of the map view in question 93 is the oldest bed

A. formation F strikes N 50 E and dips to the S. E.
B. formation G is older than formation D
C. formation E strikes N 50 E and dips to the N.W.

D. formation C is younger than formation F
E. formation G strikes N 50 W and dips to the N. E.

Questions 95 through 99 refer to MAP VI

95.* Point Reyes' coast line is a

A. raised beach
B. barrier bar
C. stack
D. area of deposition
E. wave-cut cliff

96.* Abbotts Lagoon, N. W. shoreline, is

A. enclosed by a bay mouth bar
B. enclosed by a barrier bar
C. located in a large kettle
D. an oxbow lake
E. enclosed by a barrier beach

97.* Limantour Spit is a

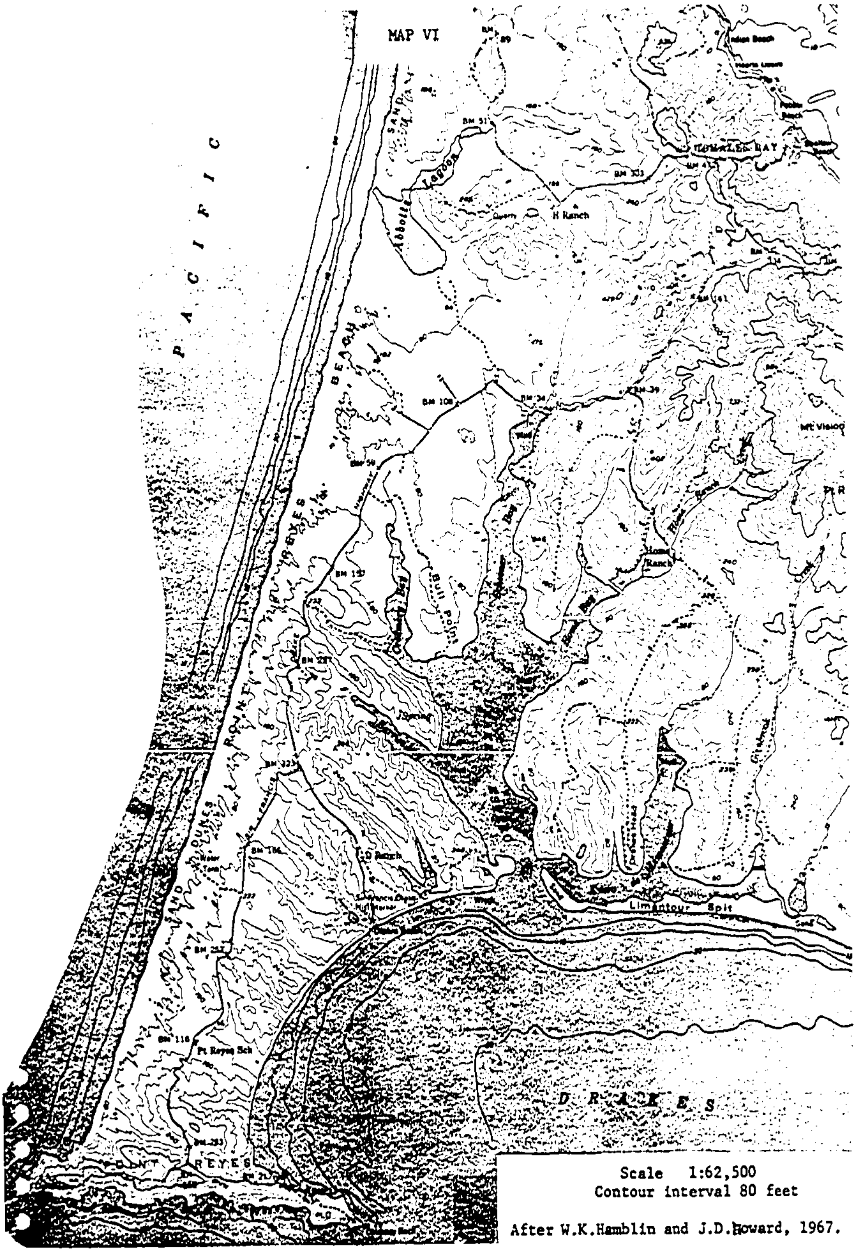
A. bay mouth bar
B. barrier bar
C. wave-cut beach
D. barrier island
E. a terminal or end moraine

98. Limantour Spit is

A. being eroded by turbidity currents
B. being extended with the aid of westward longshore currents
C. being eroded by longshore currents
D. part of an inundated shoreline
E. composed primarily of coarse gravel

99. The rocks protruding above sea level off the coast of Point Reyes are

A. transported by longshore currents
B. stacks
C. volcanic necks
D. guyots
E. jetties



Scale 1:62,500
Contour interval 80 feet

After W.K.Hamblin and J.D.Howard, 1967.

APPENDIX F

SEMANTIC DIFFERENTIAL TEST FOR ATTITUDE

Instructions*

The purpose of this study is to measure the meanings of certain things to various people by having them judge them against a series of descriptive scales. In taking this test, please make your judgments on the basis of what these things mean to you. On each page of this booklet you will find a different concept to be judged and beneath it a set of scales. You are to rate the concept on each of these scales in order.

Here is how you are to use these scales:

If you feel that the concept at the top of the page is very closely related to one end of the scale, you should place your check-mark as follows:

fair ___X___:______:______:______:______:______:______ unfair

OR

fair ______:______:______:______:______:______:___X___ unfair

If you feel that the concept is quite closely related to one or the other end of the scale (but not extremely), you should place your check-mark as follows:

strong ______:___X___:______:______:______:______:______ weak

OR

strong ______:______:______:______:______:___X___:______ weak

If the concept seems only slightly related to one side as opposed to the other side (but is not really neutral), then you should check as follows:

active ______:______:___X___:______:______:______:______ passive

OR

active ______:______:______:______:___X___:______:______ passive

The direction toward which you check, of course, depends upon which of the two ends of the scale seem most characteristic of the thing you're judging.

If you consider the concept to be neutral on the scale, both sides of the scale equally associated with the concept, or if the scale is completely irrelevant, unrelated to the concept, then you should place your check-mark in the middle space:

safe ______:______:______:___X___:______:______:______ dangerous

---

*Copy of Student Instructions for the Semantic Differential (After Osgood, 1957, pp. 83-84).

Instructions - Continued

IMPORTANT: (1) Place your check-marks in the middle of spaces, not on the boundaries:

THIS NOT THIS

______:______:______:_X__:_____X_____:______

(2) Be sure you check every scale for every concept--do not omit any.

(3) Never put more than one check-mark on a single scale.

Sometimes you may feel as though you've had the same item before on the test. This will not be the case, so do not look back and forth through the items. Do not try to remember how you checked similar items earlier in the test. Make each item a separate and independent judgment. Work at fairly high speed through this test. Do not worry or puzzle over individual items. It is your first impressions, the immediate "feelings" about the items, that we want. On the other hand, please do not be careless, because we want your true impressions.

GEOLOGY LAB ACTIVITIES

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

INTRODUCTORY LECTURE TO GEOLOGY LAB

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

GEOLOGY LAB QUIZZES

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

LAB DEMONSTRATIONS, FILMS, SLIDES, PHOTOS AND MODELS

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

STUDY OF ROCKS & MINERALS

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

STUDY OF MAPS

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

GEOLOGY LAB INSTRUCTOR

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

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1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

ME, AS A GEOLOGY LAB STUDENT

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

DEGREE OF CORRELATION BETWEEN
GEOLOGY LECTURE SECTION AND LAB

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

GEOLOGY LECTURE SECTION

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful

O. U. PROFESSORS

1. meaningless ____:____:____:____:____:____:____ meaningful

2. constrained ____:____:____:____:____:____:____ free

3. interesting ____:____:____:____:____:____:____ boring

4. usual ____:____:____:____:____:____:____ unusual

5. good ____:____:____:____:____:____:____ bad

6. slow ____:____:____:____:____:____:____ fast

7. positive ____:____:____:____:____:____:____ negative

8. disreputable ____:____:____:____:____:____:____ reputable

9. large ____:____:____:____:____:____:____ small

10. unsuccessful ____:____:____:____:____:____:____ successful

GEOLOGY LAB SHEETS

1. meaningless ___:___:___:___:___:___:___ meaningful

2. constrained ___:___:___:___:___:___:___ free

3. interesting ___:___:___:___:___:___:___ boring

4. usual ___:___:___:___:___:___:___ unusual

5. good ___:___:___:___:___:___:___ bad

6. slow ___:___:___:___:___:___:___ fast

7. positive ___:___:___:___:___:___:___ negative

8. disreputable ___:___:___:___:___:___:___ reputable

9. large ___:___:___:___:___:___:___ small

10. unsuccessful ___:___:___:___:___:___:___ successful