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AUTHOR Stoever, Edward C., Jr.

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ABSTRACT

The National Association of Geology Teachers (NAGT) conducted an assessment of the implications of current studies encompassing the theories of continental drift, polar wandering, sea-floor spreading, and plate tectonics to K-12 education, and presented in this document recommendations for the incorporation of these concepts into school curricula. A detailed description of the current status of crustal evolution studies is presented. Conclusions drawn at the conference indicate the desirability of incorporation of these topics, as well as the feasibility of the incorporation. Recommendations show grades six through ten as primary targets. An organizational scheme is presented, as are charts showing how new information, ideas, and materials would be processed for classroom use. Suggestions for preparation of curriculum materials and introductory teacher materials are suggested. The appendices include a list of conference participants, a pre-conference report, an example of a lesson activity, suggested lesson activity topics, and suggested teacher resource book contents. (Author/EB)

THE
NATIONAL ASSOCIATION
OF GEOLOGY TEACHERS

JANUARY 1975

RECOMMENDATIONS AND GUIDELINES

THE INCORPORATION OF RESULTS OF CURRENT CRUSTAL EVOLUTION STUDIES INTO K-12 CURRICULA

Edward C. Stoever, Jr.

A CONFERENCE ON K-12 CRUSTAL EVOLUTION EDUCATION
WESTERN HILLS STATE LODGE, OKLAHOMA
SEPTEMBER 16-18, 1974

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HELD AT WESTERN HILLS STATE LODGE, OKLAHOMA
SEPTEMBER 16-18, 1974

Edward C. Stoever, Jr., Director
University of Oklahoma
Norman, Oklahoma

DECEMBER, 1974

CONFEREES

Mrs. Lynette Aey
Norwich Free Academy, CT

Robert E. Boyer
Univ. of Texas, TX

John V. Byrne
Oregon State Univ., OR

William A. Dexter
St. Mark's School, TX

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SUNY-Albany, NY

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D. M. Hussong
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Don Hyatt
Worthington Schools, OH

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Oregon State Univ., OR

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Nat'l. Sci. Foundation, DC

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Highland Senior High, IN

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Weston Observatory, MA

Carol J. Stadum
Huntington Beach High, CA

Robert E. Stevenson
Off. Naval Research, CA

Elazar Uchupi
Woods Hole Institute, MA

Tracy L. Vallier
Deep Sea Drilling Project, CA

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INTRODUCTION

I. BACKGROUND

The National Association of Geology Teachers (NAGT) has conducted an assessment of the implications of current studies of crustal evolution* to K-12 education, and has developed recommendations for the incorporation of these concepts into school curricula. The study was supported by the National Science Foundation. The objectives of the assessment were:

1. To determine the desirability of recommending specific action for introducing crustal evolution concepts into K-12 curricula.

2. To assess the feasibility of preparing this curriculum supplement.

3. To develop specific recommendations based upon the meeting of the first two objectives.

A Pre-Conference meeting of seven secondary school teachers and college science educators (Appendix A) met in Norman, Oklahoma on July 29-30, 1974, and prepared a report considering the first of these objectives (Appendix B). This group discussed the importance of crustal evolution concepts to K-12 education, surveyed the status of crustal evolution studies in K-12 curricula, explored the needs of crustal evolution studies in K-12 curricula, and suggested guidelines and constraints for a conference to consider more fully objectives 2 and 3 above.

On September 16-18, 1974, 22 scientists, secondary teachers, and college science educators (including five who were at the pre-conference meeting) met at Western Hills State Lodge, near Wagoner, Oklahoma, and concentrated on the last two objectives. They concluded that it was both desirable and feasible to incorporate crustal evolution educational materials into grades 6-10 science courses and curricula. The report that follows gives the justification for this conclusion and describes the objectives and activities designed to achieve objective 3 above.

It should be stressed that the conferees view the crustal evolution educational materials as supplements, rather than as replacements, to existing curricula and courses. The materials should be designed as flexible instructional units that can be used by teachers and instructors to enhance conventional curricula in all science areas.

* The phrase "crustal evolution" as used in this report encompasses the theories of continental drift, polar wandering, sea-floor spreading, and plate tectonics.

II. CURRENT STATUS OF CRUSTAL EVOLUTION STUDIES

The concept that continents and ocean basins have not always been in the same position relative to each other or had the shape, size, and features that they exhibit today has been heard, off and on, in geological discourse for more than 100 years. The most pervasive idea has been that continents have moved, relative to each other, across the surface of the earth. This idea is called continental drift. Early proponents of continental drift were open to criticism because they had proposed a mechanism that was shown to be mechanically unsound.

During the second half of the 20th century, improved geological and geophysical data gathering techniques have permitted more rigorous examination of the ocean floors. These studies led to some perplexing conclusions about the sea floor; conclusions inconsistent with the idea of younger, lighter continental blocks floating on older, denser, primitive crust. Such recent studies of the ocean basins indicated the youthfulness of mid-ocean ridges, the restriction of seismicity to the ridges, the paucity of extensive sediment cover, and the increase in age of sediment cover away from the ridges. Based on these observations it has been concluded that the ocean basins are geologically young features. Although ocean basins have existed throughout geologic time, most of the present sea floor is thought to be Post-Paleozoic in age.

In the early 1960's, data on the magnetic properties of the sea floor became available. A chronology of the evolution of the ocean basins was developed from the lateral variation of the residual magnetic field away from mid-ocean ridges. These investigations have shown magnetic lineations that parallel the ocean ridges and form mirror images of one another on either side of the ridges. Correlation of magnetic anomalies with known magnetic chronology on land indicates that the oceanic basement becomes progressively older away from the ridges and that the magnetic strips of ocean crust are, in effect, "growth rings." Such a conclusion was also verified by deep-sea drilling results which showed that sediments became progressively older away from the ridges. These phenomena have been explained as a consequence of the continents and the ocean basement drifting away from the mid-ocean ridges. Previously proponents of continental drift visualized the continents plowing through the oceanic basement. Present proponents of drift believe that both the continents and oceanic basement are created at the ridges, and are slowly moving away from spreading centers.

Intense oceanographic investigations during the decade after this concept was proposed clearly show that the earth's crust is in a state of active formation. Although some geologists remain unconvinced, the growing mass of information is best explained within the framework of the sea-floor spreading concept.

Every concept of earth science, every discipline, and all scientists are entering a new era. The earth's crust is dynamic, constantly changing, at measurable rates, and the places where the action takes place are known and can be examined. For the first time, there is a scientific rationale for the biological and geological evolution of the Earth.

The revolution continues. Since the mid-1960's data have accumulated permitting a closer evaluation of crustal structure. Not surprisingly the simple spreading picture first proposed is slowly changing.

The conception we now have of the earth's surface is that of plates in motion. The boundaries of these plates produce the earth's tectonic fabric. Where the plates are separating at mid-ocean ridges, new crust is being formed. Where plates underthrust one another or collide, old crust is being destroyed, and new crust is being formed by the deformation of sediment wedges and by the partial melting of such wedges and incorporation of oceanic crustal material within the resulting mountain belts. At sites where plates are sliding past one another, faults and earthquakes occur but no crust is being formed or destroyed.

One needs only to scan earth science literature of the 1960's and 1970's to appreciate the importance of this concept and to see the speed with which it has dominated earth science thinking.

The nearly universal recognition of the importance of plate tectonics by research scientists is rivaled by those in industries devoted to developing resources of the solid earth. Petroleum, mining, coal, water (on a global scale) are all rapidly reorganizing exploration techniques to take into account concentration processes in light of moving, separating, and colliding plates.

CONCLUSIONS

I. IT IS HIGHLY DESIRABLE THAT CURRICULA AT THE PRE-COLLEGE LEVEL INCORPORATE AND REFLECT MATERIAL RELATING TO CURRENT AND ONGOING STUDIES INTO THE EVOLUTION AND HISTORY OF THE EARTH'S CRUST AND UPPER MANTLE.

1. Involving Students in a Major Scientific Revolution in Progress Offers a Unique Educational Opportunity.

Current crustal evolution advances are a "breaking story" that students are living through today. Teachers and students have a unique opportunity to share in the unfolding of this educationally important and exciting intellectual advance. In the earth sciences the new concepts could rank in importance with the Hutton and Lyell concept of uniformitarianism, Smith's demonstration of faunal succession, the Darwin theory of evolution, and the development of radiometric dating. As with each of these scientific breakthroughs, the new crustal evolution concepts have touched off a period of accelerated activity that promises to expand greatly our knowledge of the earth and to deepen our understanding of its history.

Current crustal evolution studies clearly deserve to be recognized as a scientific revolution of major proportions. The number and calibre of participating scientists; the incidences of interdisciplinary interactions; the number and calibre of papers appearing in scientific and lay publications; the number of international, national, and regional conferences; and the scientific changes already initiated in programs designed to exploit commercial and educational aspects, all attest to this.

Crustal evolution is admirably suited by its nature to introduce notions of the development of a scientific theory; to demonstrate the methods and problems involved in the collection, manipulation and interpretation of scientific data; and to illustrate the variability of theories explaining the origin and operation of natural phenomena. It is also amenable to treatment at different levels of comprehension and is capable of stimulating students with a wide range of intellectual ability.

2. Current Crustal Evolution Theories Afford a Unifying Theme for Science and Educational Curricula.

A need exists to study current crustal evolution concepts because of their potential as a unifying theme for the earth sciences. Whether correct in detail or not, current theory is capable of providing a rational conceptual framework for important geological processes such as the origin and distribution of igneous and metamorphic rocks, the distribution of sedimentary rocks and fossils, the distribution of volcanoes and earthquakes, the occurrence and distribution of some mineral and energy fuel deposits, and the origin of orogenic belts. New theory appears to indicate relationships between many geological processes formerly thought to be unrelated, and to increase our understanding of earth history.

Land-use planning, natural-disaster forecasting, and energy and environmental considerations are but some of the areas in which human lives will be affected. Other areas of education also affected include: the climatic history of the earth, its chemical history, the evolution of life, and the history of the earth's present geography.

3. Inclusion of These Concepts is Compatible With Current Trends Toward Unification of Science Education.

Recent developments in science education reveal a trend toward a unification in science education. Growing out of earlier interdisciplinary curriculum projects such as the Earth Science Curriculum Project (ESCP) and the Intermediate Science Curriculum Study (ISCS), more recent unified science courses have brought together content and processes that are drawn from science, mathematics, and the social sciences.

Crustal evolution curriculum activites lend themselves particularly well to a unified approach of teaching science. Although dealing primarily with geological aspects of the solid earth, crustal dynamics relies heavily on chemistry, physics, biology, oceanography and meteorology. For example, much of our understanding of crustal evolution is based on information derived from a broad spectrum of geophysical data. By the same token, rock samples recovered in deep sea drilling and sampling are analyzed by chemical techniques and any fossils they contain are interpreted in the light of biological knowledge of their modern counterparts. In turn, crustal evolution models provide useful frameworks for the analysis of chemical, physical, and biological data.

The unification of socio-economic studies is equally important in crustal evolution curriculum supplements. The role of crustal dynamics in the formation of mineral resources such as ore deposits, fossil fuels, industrial minerals, and geothermal resources has had - and will continue to have - a distinct effect on man and his physical needs. Geologic features such as oceans, continents, volcanoes, earthquakes, and glaciers are also related to crustal dynamics. These features have not only determined the geographic distributions of climates and life forms, but have had an important role in shaping human history.

The proposed approach to the study of crustal evolution is not only compatible with the trend toward unification of science; it also clearly reveals the interdependence of the social and natural sciences. Equally important, the study of crustal dynamics should be an effective means of moving new knowledge from the scientific research community into the educational system. This transfer would be in an interdisciplinary form rather than discrete units of geology, biology, physics, chemistry, or social studies.

II. PRESENT CURRICULA DO NOT ADEQUATELY INCORPORATE APPROPRIATE MATERIAL, NOR DO ADEQUATE MECHANISMS FOR ITS EFFECTIVE INCORPORATION EXIST

1. Results of a Study of the Current Status of K-12 Curricula and Materials.

The Pre-Conference Meeting considered the current status of K-12 education in regard to incorporation of plate tectonic concepts and related topics into curricular and ancillary materials (Appendix B). The general finding, based on the experience of the conferees, was that there has been very little impact on classroom activities to date, and little in the way of help appears to be on the way. This conclusion is supported by the results of attempts to locate existing materials, sources, and projects through correspondence with 138 persons in a position to know of such information, who represented all 50 states. A review of all materials in the International Clearinghouse on Science and Mathematics Curricular Developments, for example, uncovered only three programs which included any activities whatsoever dealing with crustal evolution.

Most K-12 teachers, including those in the earth sciences, exhibit a lack of either awareness or true understanding of the importance of recent developments in crustal evolution and of their relevance to the earth sciences, to man, and to education. Existing textbooks commonly devote from a few paragraphs to a few pages on the subject, and much of this quickly becomes outdated. Except for the individual self-developed curricula and activity modules of a very few teachers nation-wide, no special attention has been paid to these concepts. In particular, there appears to have been no attempt to utilize the unifying aspects of crustal evolution theory as a logical theme for unifying science curricula. Ancillary materials that do exist are little known and less utilized. Presently, very little effort to rectify this general situation has occurred by either educational or scientific organizations which could provide such direction.

III. THE DEVELOPMENT OF K-12 CURRICULAR MATERIALS WHICH REFLECT ONGOING CRUSTAL EVOLUTION RESEARCH AND THE INCORPORATION OF THESE INTO EXISTING K-12 COURSES OF INSTRUCTION, IS FEASIBLE

The participants in this conference were representative of producers (active researchers), translators (science educators and teacher educators), and consumers (teachers) of crustal evolution information appropriate to K-12 education. Many types of relevant experience and involvement, e.g. past curriculum projects, professional educational and scientific organizations, agencies and institutions, commercial publishers, and government agencies, were present in the group. Their unanimous conclusion is that the goal of incorporating the results of ongoing crustal evolution research both is attainable and highly desirable. Many resources, facilities, and mechanisms for this realization presently exist, and their successful coordination and utilization greatly enhance the likelihood of the program's success.

In the following sections of this report a number of recommendations and guidelines for attainment of this goal are offered. Explicitly, the goal is:

> To incorporate materials and information derived from ongoing research and emerging theories of crustal evolution into appropriate K-12 curricula as supplements to existing curricula.

The conferees believe that this is a goal worthy of a national coordinated effort, and that its realization has the potential of an impact on science curricula far greater than that of its subject matter alone.

RECOMMENDATIONS

These recommendations constitute a plan for realizing the goal of incorporation of crustal evolution materials and information into classroom curricula. Successful attainment of these objectives should result in the goal being accomplished.

I. THIS GOAL SHOULD BE ACCOMPLISHED BY A PLAN OF ACTION ACTIVELY PARTICIPATED IN BY PROFESSIONAL SOCIETIES, GOVERNMENTAL AGENCIES AND INDIVIDUALS REFLECTING BOTH EDUCATIONAL AND SCIENTIFIC INTERESTS

Realization of the stated goal will require a close working relationship between teachers and active research scientists. Undoubtedly, this close liaison will be unique. In order for it to be effective, not only must a suitable organizational framework be found, but many related organizations must be involved, and should lend their active, self-initiated support. We believe that this will be forthcoming because there are benefits of public service, dissemination of information, mission satisfaction, and participation in a worthwhile educational improvement effort which will appeal to all parties.

II. THE PRIMARY TARGET FOR INCLUSION OF CRUSTAL EVOLUTION RELATED MATERIALS AND INFORMATION INTO CURRICULA SHOULD BE GRADES 6 THROUGH 10

It is anticipated that "spin-off" of related materials will occur in the pre-6 and post-10 levels, and particularly into physical and biological science curricula at the upper grade levels. However, the particular target area of grades 6-10 seems most appropriate for the following reasons:

1) It is intended that developed materials will be utilized by teachers and students involved in a variety of physical and biological science curricula, and earth science topics are most commonly treated within these science curricula in 6-10 level classrooms nationwide.

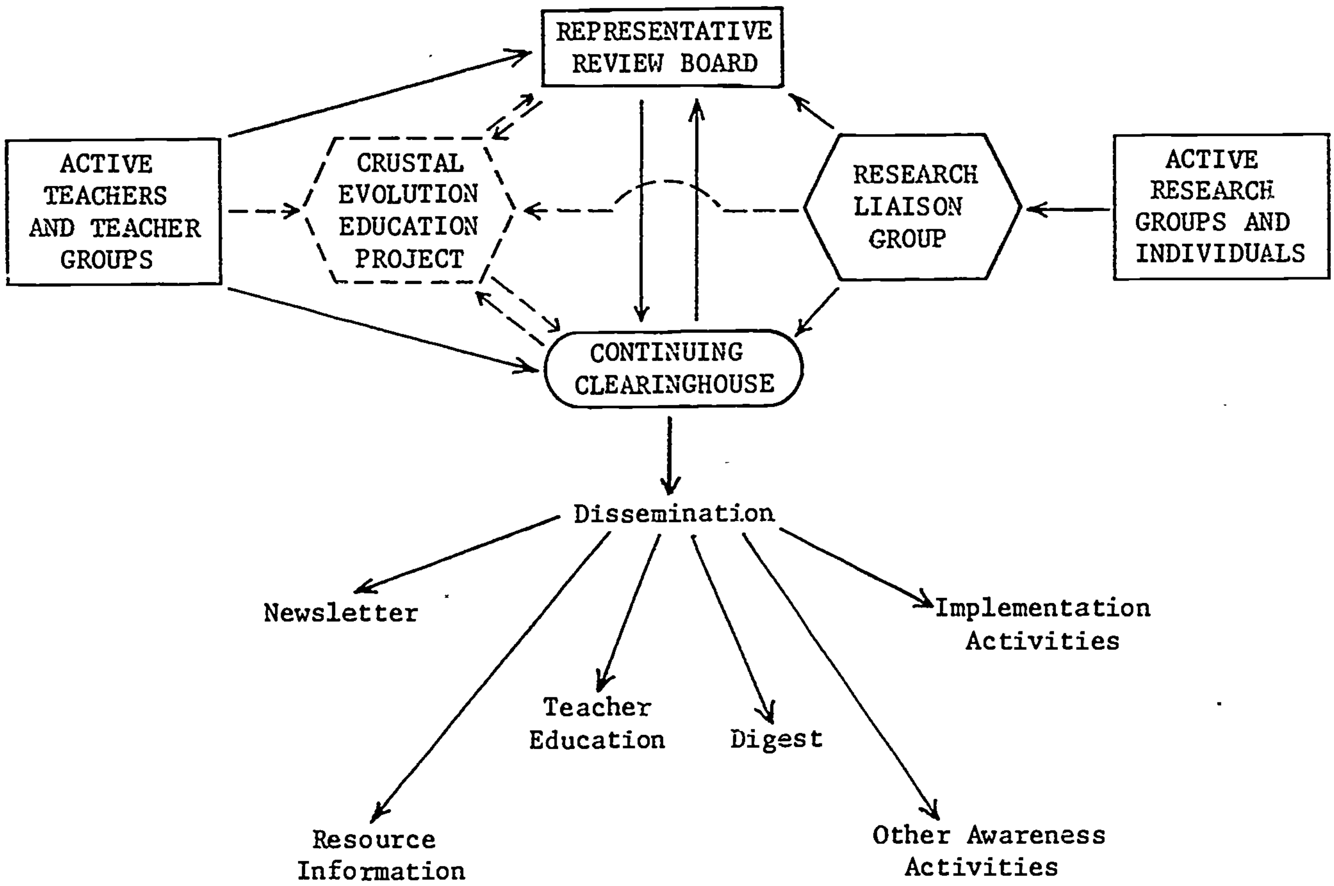
2) Teachers at these levels, because of their exposure to earth science topics, are best prepared to deal with the subject matter related to crustal evolution concepts.

3) Many of the students at the 6-10 grade levels are intellectually mature enough to assimilate these concepts, and possess the ability to recognize relevancy of the subject to self, society, and environment.

4) Finally, it is desirable initially to focus effort on a limited grade range, and the 6-10 range appears to be the most fruitful area to deal with, both in terms of the changes students are undergoing during these years, and in terms of the need for unifying curriculum concepts at these levels.

III. ACHIEVEMENT OF THE STATED GOAL REQUIRES THAT A CONTINUING AND PERMANENT MECHANISM FOR INCORPORATING MATERIALS AND INFORMATION FROM ONGOING RESEARCH AND EMERGING THEORIES OF CRUSTAL EVOLUTION BE ESTABLISHED

It is premature, perhaps, to fix specifically an organizational scheme for realizing the desired participation, interaction, and continuity. However, to illustrate the sense of this recommendation, and to provide a point of reference for subsequent recommendations, we suggest that a suitable arrangement might be as shown below (Fig. 1).



NOTE: The Crustal Evolution Education Project is specifically designated as temporary - i.e., of a finite duration.

Figure 1. CHART SHOWING HOW NEW INFORMATION, IDEAS, AND MATERIALS WOULD BE PROCESSED FOR CLASSROOM USE

The proposed "clearinghouse," which is responsible both for maintaining liaison relationships between researchers and teachers and for dissemination, should be a permanent, ongoing activity, inasmuch as the stated goal involves ongoing crustal evolution studies, and new developments are to be expected more-or-less continuously for the forseeable future.

Since no existing agency or institution presently exists which has the capability or the mission of serving as the proposed clearinghouse, it is recommended that a first step be the establishment of a development project of finite duration, hereinafter referred to as the, "Crustal Evolution Education Project." This development project would not only function to realize its own goals and objectives, but also to initiate functions which would be the continuing responsibility of the clearinghouse. More detailed discussion of these functions is presented in several of the following recommendations.

IV. A COMPREHENSIVE EFFORT, INCLUDING A SHORT-TERM DEVELOPMENT PHASE AND A LONG-TERM TRANSLATION AND IMPLEMENTATION EFFORT, IS DESIRABLE IN ORDER TO ACCOMPLISH THE FOLLOWING OBJECTIVES:

1. Activity-Oriented Materials for Students Should Be Prepared and Disseminated To Classroom Teachers

These materials should be prepared in the form of a looseleaf Teacher Activities Notebook, which should contain an initial group of activities. It would be open-ended to accept additional activities as developed later. Each activity would be structured according to the following outline:

a) An introduction to the activity with its application to other areas of study.

b) Behavioral objectives stated for the student's guidance.

c) Key words, or vocabulary, new to this activity.

d) A material list of required activity equipment.

e) A statement of the estimated time needed to complete the activity.

f) Procedure, or student investigation, which will include inquiry methods, role playing, activities, experiments, and teacher-directed demonstrations.

g) Suggested audio-visuals such as maps, overhead transparencies, tapes, diagrams, and picture prints.

h) Questions which would encourage discussion, review the activity, serve for evaluation, and/or lead to individual study.

i) A list of relevant films, articles, books, and other references.

These lessons would be descriptive, and each activity should have additional quantitative and complementary material that may be used by advanced students or classes. Parallel group activities (e.g. sediment thickness, sediment age, basement age, magnetic reversals, etc.) could culminate in the collective formation of an all-encompassing hypothesis (e.g. solution). Wherever possible available actual data and material (foraminifera and other core sample material, seismographs, magnetic profiles, manganese nodules, etc.) should be employed. Some lessons might include ancillary readings on the history of the development of the crustal evolution concept. Appendix C is an example of a crustal evolution activity, and, while not prepared according to the outline given above, is illustrative of the potential of the type of investigation or lesson to be developed for the *Teacher Activities Notebook*.

These lesson and activity packets should be developed by teachers of earth science in cooperation with active research scientists. They should be so designed as to be capable of being used independently, or integrated with other existing disciplinary and/or interdisciplinary materials. Appendix D is a list of possible topics, developed in correlation with the suggested table of contents of the proposed Introductory Teacher Packet.

2. Teachers Should Be Provided With the Fundamental Concepts and Understandings Necessary to Communicate Crustal Evolution Concepts

This should be incorporated in an *Introductory Teacher Packet*, ideally containing no more than 50 looseleaf pages of text and ample, easily reproducible illustrations, that will follow the outline attached as Appendix E. This publication should provide the background material necessary to utilize the curricular materials recommended in the previous section. It should be developed by scientists and written for teachers by teachers aided by scientists. It should also contain a rationale for teaching crustal evolution at grades 6-10; and an overview and guide to activities available through the Clearinghouse. (next section).

3. A Clearinghouse for Continuing Compilation and Dissemination of Crustal Evolution Information and Educational Materials Should Be Initiated.

At present neither an effective means of communication with all target teachers and students, nor a center for preparation of appropriate material and information exist. Therefore, the development of an ongoing task force which would serve as a Clearinghouse, and which would communicate with its users through publication of a *Crustal Evolution Digest*, is recommended. The objectives of this group would be the dissemination of current and up-to-date information on crustal evolution, along with other modern earth science concepts, to teachers and schools. The Clearinghouse could:

a) Develop a communication chain to users through publication of a Crustal Evolution Digest (in a looseleaf notebook format suitable for inclusion with the Introductory Teacher Packet).

b) Develop free or low-cost teaching materials.

c) Serve as a clearinghouse for slides, photographs, maps and other visuals received from research organizations. The research facilities should be conditioned to sending these materials, along with explanatory information, to the clearinghouse.

d) Prepare and distribute lessons and activities that might include masters for overhead transparencies, work sheets, and diagrams.

e) Serve as a quality-control board for contributed material. Edit, revise, identify errors and omissions, and prepare for dissemination.

f) Work closely with some commercial firm to develop modules and units in a program that perhaps is designed to modify, support, etc. existing curricula, not to establish a curriculum of its own. The production of lab materials should be such that they may not be beyond the reach of teachers with very limited budgets.

g) Provide an outlet for news stories (of recent importance) or feature stories on a specific topic.

h) Provide for teacher feedback and interaction.

i) Allow space for an "activity corner" which would deal with student investigations and teacher demonstrations solicited from classroom teachers.

j) Provide a medium for teachers to exchange material (rocks, minerals, fossils, and experimental data).

k) Provide a means of monitoring the effectiveness of the program.

4. Provision Should Be Made, Concurrent With Development of Materials and Communication Strategies, for Making Teachers Aware of the Resources Available and for Making Available Training Opportunities.

Experience of previous science education improvement projects has shown the critical importance of efforts in dissemination and implementation that parallel and occur coincident with the materials development. The funding of a materials development program must adequately provide for dissemination and implementation--in order to maximize the utilization of materials with the target population.

Three phases are proposed: awareness, promotion, and implementation. These would occur simultaneously and continuously during the lifetime of the materials development program. Furthermore, and most importantly, these functions would be the primary responsibility of the Clearinghouse, described in Section 3 (and which is envisaged as a continuing function of NAGT).

The function of the awareness phase would be to alert the science education community to the existence of the program. This phase would include:

a) A monthly newsletter designed to keep science educators abreast of program developments and of changes occurring in the teaching of the earth sciences generally. The early issues of the newsletter might contain examples of materials included in the Teacher Activities Notebook. It would have a "tear-out and mail-back" card requesting additional information concerning the project. The newsletter would be sent to individuals in a mailing comprised of members of the National Association of Geology Teachers, the secondary school and college membership of the National Science Teachers Association, the Association for the Education of Teachers of Science, and the National Science Supervisors Association. It would also be sent to state education agencies and commercial suppliers of science education materials.

b) Short articles and advertisements regarding the program would be submitted to: The Science Teacher, Science and Children, The Journal of College Science Teaching, The Journal of Geological Education, Geotimes and the Newsletter of the Association for the Education of Teachers of Science.

c) Presentations concerning the program would be made at regional and national meetings of the National Association of Geology Teachers, National Science Teachers Association, and The Geological Society of America. Booths at these meetings would disseminate information and materials.

d) Local free announcements would be prepared for use by educational television and radio stations.

The Promotion phase would include responding to individuals seeking additional information as a result of the awareness activities. Primarily this would be accomplished through the Introductory Teacher Packet. Also, local "drive-in" workshops by local resource personnel would be promoted and assisted by the materials development staff. All developed materials would be included in the Educational Resources Information Center (ERIC) process.

The staff would stimulate implementation activities for those teachers wishing to use materials with their classes. This is the most critical phase of the program. A network of science educators who would respond to teacher training needs in their areas would be developed, trained, and assisted by the staff. Their response could take various forms, including one-week intensive short courses, in-service courses meeting periodically through the school year, or informal individual consulting and assistance to school systems incorporating the material into their curricula. With the encouragement and support of Project and Clearinghouse staff, these science educators would be encouraged to seek funding for these activities through their universities, Federal agencies or other sources.

6. A Means of Monitoring the Overall Effectiveness of the Total Incorporation Should Be Provided.

A Review Board should be established to serve as an overall governing body on policy and direction of the program.

Duties of the Review Board:

1. Meet periodically with the program staff to review the materials produced.
2. Establish policy regarding the overall nature and content of the materials produced.
3. Evaluate the ongoing effectiveness of the program and implement changes which they may deem desirable, including staff changes, reorganization of format of materials being produced, alterations in the nature of subject matter being treated, and the like.
4. Suggest and implement new dimensions to the program.
5. Seek continual support of the program by overseeing preparation of grant proposals.
6. Promote interaction with organizations which exist or may be initiated that have related interests.

Structure of the Review Board:

The Review Board might consist of eight members, with specialty area representation (two each) from oceanographer-geophysicist research scientists, secondary school earth science teachers, earth science curriculum specialists, and college-university earth science (geology, geophysics, oceanography) teachers.

Members of the Review Board would have two-year terms, so arranged so that four terms expire each year, one representing each of the four specialty areas listed above. No member would serve for more than two successive terms.

The Review Board would elect its own chairman and vice-chairman. Each year the vice-chairman would succeed to chairman the following year. The chairman and vice-chairman would represent different specialty areas. No member of the Review Board would serve as vice-chairman or chairman for more than one term.

Meetings of the Review Board:

The Review Board would convene at least once each year, but could hold other meetings as they considered appropriate.

V. THE NATIONAL ASSOCIATION OF GEOLOGY TEACHERS IS THE LOGICAL ORGANIZATION TO COORDINATE THE IMPLEMENTATION OF THESE RECOMMENDATIONS

The National Association of Geology Teachers represents a broad spectrum of representative membership in fields of study and areas of involvement in both education and research in the earth sciences. It's constitutional commitment is to the, "dissemination of information in the geological sciences." It is therefore logical that the Association be responsible for the implementation of these recommendations, including:

1. preparation of a proposal for implementation,

2. establishment of the initial Review Board (p. 14),

3. maintaining the physical housing of the Clearinghouse,

and 4. acting as the administrator and sponsoring organization for all subsequent activities.

POTENTIAL RESOURCES

A variety of existing agencies and organizations are ideally structured to offer assistance in the implementation of this program. There is strong reason to believe that these agencies and organizations would cooperate fully with efforts to develop and disseminate educational materials related to the proposed crustal evolution study project.

a) Resource Material and Personnel

Embodied within the existing framework of many agencies and organizations are offices of public information willing to supply resource materials in the form of literature, visual aids (slides, films, photographs) and similar educational products.

Included among these are National Oceanic and Atmospheric Administration (Office of Sea Grant), Sea Grant Institutions, Oceanographic Education Center, National Oceanographic Survey, U.S. Geological Survey, American Geological Institute, Marine Technology Society, National Science Teachers Association, American Academy for the Advancement of Science, National Academy of Science, National Association of Geology Teachers, Deep Sea Drilling Project, U.S. Naval Oceanographic Office, and American Meteorological Society.

Certain personnel from these organizations are interested in educational information on crustal evolution and will lend their expertise in the development of scientifically sound materials on this subject.

b) Dissemination of Information

In order that the materials developed might be transferred from the research community to the educational system, existing societies and organizations with local, regional and national meetings can be utilized effectively. Workshops and other sessions for both distribution and explanation of the materials can be organized for these meetings and tailored to the needs of the anticipated attendees. This approach is therefore doubly effective: societies and organizations afford a ready-made audience; the educational workshops provide important content-oriented science sessions of a unifying nature to these meetings.

Societies and organizations capable of disseminating this information would include state education agencies, regional curriculum centers, Sea Grant Institutions, and professional organizations such as the Geological Society of America, National Association of Geology Teachers, National Science Teachers Association, state academies of science and state science teachers organizations.

Most of these societies and organizations publish and distribute newsletters, periodicals, and other printed material to their respective memberships and, in some cases, for public distribution. Such publications provide an ideal medium for even more widespread distribution of the results of current developments in the proposed Crustal Evolution Study Program.

Certain educational materials, particularly those involving visuals and inexpensive hardware, might best be developed and distributed through cooperative efforts with commercial firms.

c) Financial Support

A program of this magnitude requires some degree of financial support if it is to be developed and successfully implemented. Sources of funds might naturally include federal agencies such as the National Science Foundation, the National Oceanic and Atmospheric Administration, the Office of Education, as well as private foundations. On a more limited scale, financial support for implementation might be obtained from state education agencies, continuing education departments of academic institutions, and professional societies.

APPENDIX A

PARTICIPANTS IN THE NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE PROJECT

° Mrs. Lynnette Aey
Norwich Free Academy
Norwich, Connecticut

°* Robert E. Boyer
University of Texas
Austin, Texas

+* John V. Byrne
Oregon State University
Corvallis, Oregon

William A. Dexter
St. Mark's School of Texas
Dallas, Texas

Paul J. Fox
State University of New York
Albany, New York

* Thomas E. Hendrix
Indiana University
Bloomington, Indiana

* Dale T. Hesser
Cicero High School
N. Syracuse, New York

D. M. Hussong
Hawaii Institute of Geophysics
Honolulu, Hawaii

Don Hyatt
Worthington Public Schools
Columbus, Ohio

LaVerne D. Kulm
Oregon State University
Corvallis, Oregon

John A. Maccini
National Science Foundation
Washington, D.C.

Vincent Matthews III
University of Northern Colorado
Greeley, Colorado

* William H. Matthews III
Lamar University
Beaumont, Texas

Victor J. Mayer
Ohio State University
Columbus, Ohio

Gerry Messmer
Highland Senior High School
Highland, Indiana

° Robert W. Ridky
University of Maryland
College Park, Maryland

Maurice L. Schwartz
Western Washington State College
Bellingham, Washington

+° James P. Schweitzer
Louisiana State University
Baton Rouge, Louisiana

+° Henry Silverstein
Beach Channel High School
Rockaway Park, New York

James W. Skehan, S.J.
Weston Observatory, Boston College
Weston, Massachusetts

° Carol J. Stadum
Huntington Beach High School
Huntington Beach, California

° Mrs. Marjorie Starr (Project Secretary)
University of Oklahoma
Norman, Oklahoma

* Robert E. Stevenson
Office of Naval Research
La Jolla, California

°* Edward C. Stoever, Jr. (Project Director)
University of Oklahoma
Norman, Oklahoma

Elazar Uchupi
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Tracy L. Vallier
Deep Sea Drilling Project Office
La Jolla, California

* Denotes Steering Committee Member
° Denotes Pre-Conference Conferee
+ Did not attend Conference

APPENDIX B

REPORT OF
PRE-CONFERENCE PLANNING AND ASSESSMENT MEETING
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE PROJECT

Contents

*PLEASE NOTE: The intent of the pre-conference assessment and planning meeting was to prepare materials for the conference. Time and resources permitted only a reconnaissance survey of curriculum material currently available. These listings should not be quoted without further analysis. The Conference Committee would appreciate any errors or oversights being brought to their attention.

APPENDIX B

REPORT OF
PRE-CONFERENCE PLANNING AND ASSESSMENT MEETING
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE PROJECT

INTRODUCTION

The objectives of this project are to answer two main questions: (1) What curricular needs exist in K-12 science education as a consequence of the implications to man's future activities of the new concepts and theories of crustal evolution arising largely from recent and current oceanographic investigations; and (2) What recommendations and guidelines can be formulated for meeting the identified needs? A Pre-Conference Meeting, held in Norman, Oklahoma on July 29-30, 1974, concentrated on the first of these questions; the Conference itself will concentrate on the second question.

This Pre-Conference report is intended to expedite the work of the Conference, and to allow Conference participants to focus their attention more readily and quickly on the development of specific recommendations and guidelines. It is also expected that the results of this Pre-Conference meeting will be further modified and expanded at the Conference proper, and will contribute to the final product of the Conference.

The Pre-Conference meeting consultants considered four principal questions: (1) What is the importance to K-12 education of current developments in crustal evolution theory; (2) What is the current status of K-12 education in regard to these developments; (3) What are the K-12 curricular needs in light of these developments; and (4) What parameters and constraints should govern the recommendations and guidelines developed by the Conference? The results of the consultants' deliberations are presented in the following sections, followed by an appendix containing other relevant material, and including some comments received from correspondents during preparation for the Conference (Appendix 8).

1. WHAT IS THE IMPORTANCE TO K-12 EDUCATION OF CURRENT DEVELOPMENTS IN CRUSTAL EVOLUTION THEORY?

1. A contemporary course in the earth sciences requires some understanding of plate tectonic theory, continental drift, sea-floor spreading, etc., because these have such wide-spread ramifications to the earth sciences, including but not limited to:

   a. Offering a contemporary explanation of mountain building, and the origin of igneous and metamorphic rocks.
   b. Offering an insight into the spatial distribution of rock types, mountains, past and present flora and fauna, climatic patterns, etc.

2. Inclusion in curricula of appropriate material affords a unique opportunity for ongoing insight into scientific thought and the nature of science.

3. The developing concepts and theories are closely interrelated with and afford a unifying framework for other areas of science - for example: biology (distribution of flora and fauna), physics (earth's magnetic field), chemistry (distribution of elements), physical geography, etc.

4. The fact that these developments are constantly in the news demonstrates a need for increased scientific literacy on the part of the general population.

5. The concepts of continental drift, sea-floor spreading, and plate tectonic theory dramatically emphasize the ephemeral nature of the earth, and the fact that the earth is constantly undergoing change.

6. The developing theories have important implications to man's current and future activities and needs, i.e. - geothermal heat, earthquakes, faults and fault movements, the activity of volcanoes, etc.

7. The developing theories have important implication to the continuing search for and the development of mineral and energy resources.

8. The impact on future natural resource explorations will contribute further to increased international interaction among nations, a matter of concern for all citizens.

9. The dramatic aspects of the concepts of continental drift, sea-floor spreading, plate tectonics, differential vertical movements, and volcanic and earthquake activity are intrinsically appealing to students, and can contribute greatly to their motivation to learn.

10. An awareness of what is ongoing in oceanographic investigations and its relevance to man's future is essential to all citizens, and an understanding of oceanographic geological and geophysical investigations is an essential part of a complete marine science educational curriculum.

NOTE: Pertinent to this question might also be some of the statements included in the original rationale submitted as part of the conference proposal (Appendix 7).

2. WHAT IS THE CURRENT STATUS OF K-12 EDUCATION IN REGARD TO THESE DEVELOPMENTS?

Generally speaking, the answer to this question is, "very little." From the first-hand knowledge of Pre-Conference meeting consultants, and from such investigations as were carried on prior to this meeting, it would appear that the only concentrated efforts to incorporate appropriate material into K-12 curricula in the nation are those being carried out by individual teachers working more-or-less in isolation, and motivated by their own personal feelings of concern over the implications to K-12 education and student needs. Essentially, the answer to this question is reflected in the list of curricular needs included in the next section, and also in the relatively scant list of pertinent materials and publications included in several sections of the appendices to this report.

It should be emphasized that time and resources have not permitted an exhaustive survey of current practices in regard to this question, nor has it been possible to exhaustively investigate all of the materials and publications cited. Nevertheless, the expertise reflected in the Pre-Conference-meeting consultants and others to whom inquiries have been addressed, and the list of materials and references which could be compiled from the contributions of these persons, are probably fairly representative of the current status of K-12 education in this regard. Some general impressions gleaned from the work of the Pre-Conference group and the Steering Committee are noted in the following paragraphs:

Organizations. Save for the current and growing interest on the part of the National Association of Geology Teachers, no particular emphasis on K-12 education appears to be present. Organizations which potentially might play a useful role include NAGT, the American Geological Institute, the Marine Technology Society, and the National Science Teachers Association.

Institutions. To our knowledge, no institution of higher education is currently concentrating on relevant educational materials and/or teacher education for the K-12 level. Four of the Sea Grant institutions (Louisiana State University, Oregon State University, University of Rhode Island, and Texas A & M University) have done some work at the K-12 level, but almost exclusively in the biological sphere. A potentially useful vehicle for curriculum dissemination and implementation might exist through efforts such as the 2nd National Marine Education Conference (the first was in Beaufort, North Carolina in 1970), held August 26-30, 1974, at the University of Rhode Island, a Sea Grant institution.

School Systems. There are several thousand programs in marine science offered in secondary schools throughout the nation. However, there is no universally suitable text in marine science for the secondary level, and a few of the programs rely on any one of the more than 25 college texts available. While many of these devote an adequate, if not entirely current, treatment to crustal phenomena, the reading and comprehension levels of most render their use in secondary schools marginal at best. Moreover, the tenor of most secondary marine science programs is biological rather than physical or geological. Very, very few of these, to our understanding, emphasize sea-floor spreading or plate tectonics.

Research Installations and Government Agencies. None of these has any programs aimed specifically at the K-12 level, though most do have public information (PR) material of possible usefulness to teachers. However, the existence of this information is largely unknown to teachers, and very difficult of access.

Secondary Textbooks. Some material on crustal evolution is contained in less than half of the secondary "earth science" texts known to us. However, treatment is commonly only 1-3 pages, and mostly out-of-date. Better coverage is present in some recently published college-level texts, but their utility in secondary schools is questionable.

3. WHAT ARE THE K-12 CURRICULAR NEEDS IN LIGHT OF THESE DEVELOPMENTS?

1. Whatever is recommended and/or developed in the way of curriculum materials, there is a need for one or more continuing mechanisms for inexpensive (free!) dissemination of information and activities and materials - i.e. newsletter, workbook, etc.

2. A "little" source-book or activity or idea book of what's available on oceanography/crustal evolution curriculum and activities currently, and where and how much, and perhaps even including some sample activities, should be produced now. (Could or should the Conference itself produce this?)

3. A particularly great need exists for mechanisms for getting teachers aware of the thrust of plate tectonics and crustal evolution and oceanographic studies, and their educational relevance to pre-college curricula.

4. Active researchers should be directly involved in passing along information and strategies for educational activities and materials to teacher educators and teachers. How?

5. Color slides and prints of relevant material being developed concurrent with oceanographic and crustal research activities should be made available readily and cheaply to teachers.

6. There should be a national coordinating effort in oceanographic education (like NASA), by somebody, somewhere, somehow, and at the top.

7. Models for accumulating "neat" classroom activities, synthesizing and modifying them, and disseminating them effectively, should be developed.

8. Past experience of curriculum innovation efforts dictates a need for providing for ongoing support mechanisms for continuing the thrust of any innovative efforts such as contemplated. There is a great need for much greater availability, at reasonable costs, of more and better tools and means for presenting concepts to students - and particularly for things appropriate to many different kinds of student populations. These include:

a. Tools and devices (non-verbal and non-reading stuff particularly) for presenting crustal theory concepts visually.
b. Tools and devices (also particularly non-verbal and non-reading) for visual presentation of basic concepts, such as: crustal stress simulators, wave simulators, dating techniques utilizing diatoms and forams, simulation of convection currents, simulation of pressures at depth, representation of time, etc.
c. Readable expositions and review papers on specific subjects.

9. A need exists for an annotated bibliography of current materials available relating to geological and geophysical oceanography, crustal evolution theory, etc.

10. There is a very important need for an ongoing program of educating teachers. A good example of this is the slow implementation of ESCP in the country, due mainly to the lack of teachers capable of effectively handling the course. With new information and new materials coming out continually, a mechanism for continual updating and improvement of teacher background is vital.

4. WHAT PARAMETERS AND CONSTRAINTS SHOULD GOVERN THE RECOMMENDATIONS AND GUIDELINES DEVELOPED BY THE CONFERENCE?

1. The manner in which ideas and theories have been developed and tested should be stressed.

2. The cost of any materials to be developed must be kept minimal!

3. Whatever is developed should not have built-in indestructibility. Ideas are changing, and developments are occuring so rapidly, that the ability of teachers to easily up-date curricula must be an inherent feature of any recommendations.

4. The needs of all kinds of teachers, not just the fortuitously experienced and highly motivated and fortunately situated teachers, should be kept uppermost in any recommendations and subsequent action plans.

5. Materials useful to teachers and students which are already being produced, such as NSF's color glossy brochure on the Deep Sea Drilling Project, should be made available in quantity and free to teachers (the one mentioned costs 75 cents!).

6. The concern of the Conference should be for oceanographic/crustal evolution education for every student - not just for the science-bound or prospective science student.

7. Any recommendations developed should avoid being presented in the form of, "here's another nifty new curriculum."

8. Recommendations should reflect concern for the diversity in range of student needs and abilities and classroom environments, and the broad spectrum of classroom settings.

PARTICIPANTS IN PRE-CONFERENCE MEETING

Mrs. Lynette Aey
Norwich Free Academy
Norwich, CT

Robert E. Boyer
Geology Department
University of Texas
Austin, TX

Robert W. Ridky
Science Teaching Center
College of Education
University of Maryland
College Park, MD

James P. Schweitzer
Department of Marine Sciences
Louisiana State University
Baton Rouge, LA

Henry Silverstein
Beach Channel High School
Rockaway Park, NY

Carol J. Stadum
Huntington Beach High School
Huntington Beach, CA

Edward C. Stoever, Jr.
School of Geology and Geophysics
University of Oklahoma
Norman, OK

LIST OF APPENDICES

APPENDIX 1

SECONDARY EARTH SCIENCE TEXT LIST
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

Abraham, Norman, et al, Interaction of Earth and Time, Rand McNally & Company, P.O. Box 7600, Chicago, IL, 1972, 388 p.

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* Harris, Miles F., et al, Investigating the Earth: Revised Edition, Houghton Mifflin Company, 110 Tremont Street, Boston, MA, 1973, 529 p. (ESCP revision).

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Suchman, J. R. and McCombs, L., Inquiry Development Program in Earth Science, SRA, Inc., 7200 South Leamington Avenue, Chicago, IL 60638, 1968.

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* Wolfe, Skornik, Fleming, and Hawkins, Earth and Space Science, D. C. Heath and Company, 285 Columbus Avenue, Boston, MA 02116, 1971. (Second Edition)

* These materials are know to contain "more-or-less modern" material on continental drift, sea-floor spreading, plate tectonics, etc.

(This compilation was drawn largely from material published under the title, "Resources and References for Earth Science Teachers," in various issues of the Journal of Geological Education, and also from a circular titled, "Earth Science Textbooks for Secondary Schools," put out by the American Geological Institute. Material in both of these sources was prepared by Charles and Janet Wall, Salisbury State College, Salisbury, Maryland.)

APPENDIX 2

SELECTED BIBLIOGRAPHY
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APPENDIX 3

K-12 CRUSTAL EVOLUTION EDUCATIONAL MATERIALS: BOOKS
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

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* Available in Paperback.

APPENDIX 4

K-12 CRUSTAL EVOLUTION EDUCATIONAL MATERIALS: FILMS & FILMSTRIPS NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

Continental Drift, 10 min., color. Nat'l Film Board of Canada.

Continents Adrift, 15 min., color. Amer. Educ. Films.

Discovery in the Deep, 5-6 min., color. NSF Mini-Documentary Film Series "Search-Encounters with Science." Film deals with Glomar Challenger and oceanic discoveries. Contact Office of Public Affairs, NSF, 1800 G Street, Washington, D. C. 20550.

Measuring and Probing the Earth, DeNoyer-Geppert, 5235 Ravenswood Ave., Chicago, IL 60640 ($43.75). A set of seven filmstrips (Diastrophism, Evidence That the Continents Have Moved, Probing the Interior of the Earth, New Discoveries About Planet Earth, The Earth's Gravity Field, Dating Geologic Events, Measuring the Earth's Size and Shape).

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Restless Earth: Earthquakes, 26 min., color, 1973. NETV Film. Includes reference to plates, DSDP, etc.

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That Very Special Ship, 27 min., color. Deep-Sea Drilling Project Films (NSF). (Free loan: Associated-Sterling Films, 866 Third Avenue, New York, New York 10022).

The Earth Beneath the Sea, 22 min., color. McGraw-Hill Text Films (8th grade and older).

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The Turbulent Ocean. ETV (?)

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What's Under the Ocean. 13 min., color. Film Associates of California. (5th grade and older).

APPENDIX 5

K-12 CRUSTAL EVOLUTION EDUCATIONAL MATERIALS: CURRICULAR MATERIALS NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

Audio-Tutorial Materials

SOLO-LEARN - Units in Earth Science; Boyer, R. E. and Matthews, W. H. III, Ward's Scientific Establishment, Inc., Rochester, NY (1974). Includes filmstrips and cassette-taped narrations with student work sheets. Topics include, Continental Drift I: A Theory is Born; Continental Drift II: Sea-Floor Spreading; and Ocean Resources.

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Sources

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TV Course Unit

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APPENDIX 6

REFERENCE MATERIALS
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

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APPENDIX 7

RATIONALE

CONFERENCE ON EDUCATIONAL IMPLICATIONS
AND DISSEMINATION OF RESULTS OF OCEANOGRAPHIC
CRUSTAL INVESTIGATIONS

(This material was part of the original prospectus for the conference proposal)

One of the purposes of the proposed conference itself is, of course, to explore fully the educational implications of the revolution in the earth sciences which is currently going on largely as a result of these oceanographic investigations, and a more definitive rationale will be one of the conference products. Nevertheless, a few generalizations can be stated now.

First and foremost, perhaps, is the fact that a next major advance in the evolution of man's study of the history and processes of the earth is occurring right now. It would appear, for one thing, that it would be both appropriate and desirable to raise the general level of public awareness of this event through appropriate inclusion in science curricula at all levels, and to involve students in what is a "breaking story." But it is also apparent at this point in time that, if the basic concepts of the plate-tectonic model are correct, this totally new way of looking at the earth will ultimately affect everyone's lives in ways as yet only partly imaginable. Different knowledgeable persons have, in fact, suggested that this on-going revolution in the earth sciences is comparable, variously, to the development of atomic theory in physics, of cell theory in biology, and, perhaps most aptly, to Darwin's theory of evolution.

Practical aspects involving people's lives include, to mention a few, the impact that the developing theory is having, (1) on oil and gas exploration, terrestrial as well as oceanic, by providing a totally new way of looking at basin development and history, at sedimentation, and at oil migration and accumulation; (2) on mineral exploration, as a result of a totally new concept of the origins and concentration processes of mineral deposits arising from a new understanding of crustal evolution; (3) and on applications of better understandings of the causes and processes of volcanic activity and earthquakes. Political decision-making, land-use planning, natural disaster forecasting, and energy and environmental considerations are but some of the areas in which peoples' lives will be affected. And not only are the earth sciences affected, but also other areas of study of the earth's history: the climatic history of the earth, its chemical history, the evolution of life, and the understanding of the history of the earth's present geography.

Involvement of students in classrooms with these developments has important general educational benefits, as well. Representing, as it does, an excellent case history of how to solve problems, inclusion in curricula of materials providing students with first-hand, topical experiences in problem-solving and with the formulation of models would appear to have particular educational advantages and merit. At the present time, teachers have practically no materials available for incorporating these new concepts and information into science instruction. Development of appropriate materials relating to the plate-tectonic model and related topics could, in manner of speaking, get the students in the science classroom in on the ground floor of the way in which problems are solved.

APPENDIX 8

SOME CONTRIBUTED SUGGESTIONS
NAGT CRUSTAL EVOLUTION EDUCATION CONFERENCE

1. One problem that exists is that no decent textbook on marine geology has been written since Kuenen's book published in 1950. The few books that have come out did so before the plate tectonics model was developed and are out of date. If some books could be encouraged, this would be a big help.

A book on plate tectonics concentrating on the oceans would also be in order. There are some books on plate tectonics but these are written by people whose knowledge of geology is rudimentary or who don't fully understand the geophysics. A collaborative effort would seem to be called for that clearly stated the data and its implications and as clearly outlined the geological constraints on the model. If the book quits at the edge of the continental shelf or even at the shoreline, it's a loser.

One of the big problems I run into with large classes of non-specialists is the language problem. Everybody likes to invent new words--verbal shorthand and if these are sprinkled through the lectures or literature, you lose your students. Coupled with this is the fact that we who deal with the earth on a steady basis have a feeling for dimensions--kilometers, fathoms, acre-feet, millions of years, etc.; while our students may not. If the student doesn't have a good feeling for how big things are, you've lost them again.

2. A great deal of time is not given to plate tectonics, because, in my opinion, the geological knowledge of my students does not allow them to comprehend all but the more superficial events. At the pre-college level our responsibility is to introduce scientific processes, the essential concepts of a subject, skills in observation, as much first hand experience as possible, and knowledge of local phenomena. With some classes, I have found that they do not like to go into a great amount of detail on this or any other topic. We have to remember that plate tectonics is very exciting to you and me, because of our training.

3. The use of "information intermix" (a technique encouraging students to role-play natural processes and their functioning) and other "games" and simulation approaches is worth exploring. I am especially interested in how concepts are generated and I think it might be interesting to work on student creative behavior through plate tectonics ideas. The development of subtle experimental models, etc. could be exciting.

4. Since the junior high school course is the place most of our youth study earth-space science, and only a small percentage take a high school geology course, we feel we must concentrate on providing a good background at that level. For that reason I would hope that the upcoming NAGT conference could place some emphasis on programs at the junior high level.

5. As you know, most of the curriculum materials for K-12 studies of the marine enviroment exist as informal, non-commercial publications of local origin. In addition such publications as Science and Scientific American are widely utilized by science teachers providing advanced courses at the high school level. Sea floor spreading is discussed to some extent in the commercial earth science texts and asside from biology teachers, earth science teachers are the ones who are teaching about the marine environment at the K-12 level.

6. I hazard several guesses about the state of the art in pre-college work:
   1. Half of the earth science teachers have majored in a field other than geology.
   2. At least half the teachers have a fair idea of how the plate tectonics

model works, in a general way, and are eager to learn more.

3. Very few know what to do with the model; most of the workshops or lectures they would have attended on this were devoted to the history of ideas and new data that have led to the model, but very little stress has been put on using the model as a tool - to predict and to be tested in detail.

Several remedies come to mind. For instance, the model provides about ten settings in which rocks form, and the origin of rocks should be explained in terms of these settings. For igneous rocks, the two main suites are ocean basement and volcanic arc. For sedimentary rocks, there are platform and deep-water origins. For metamorphic rocks, there are subduction zones, arcs, and collisions. This suggests the value of preparing an outline on petro-tectonic assemblages, and encouraging supply houses (e.g., Ward's) to put together suites of these assemblages.

Geologic history interacts with the plate model. In some situations, the model clarifies the history; in others, the history places constrains on details of the plate motion. For instance, the classic "deltas" (Queenston, Catskill, Cretaceous) say something about the timing and nature of plate motion.

Another remedy, and perhaps the most important one, is case studies. We lean on this in our environmental science text, because we are convinced that actual situations give meaning to principles and theory. High school teachers probably need case studies more than people who are doing research or reading professional journals in the earth sciences. One solution would be to outline instructions for a class project to synthesize data from one of the JOIDES legs, and perhaps to make the Pitman-Talwani North Atlantic paleomagnetic data available in a simplified form. The project might take 3 weeks or 2 months and it would be chaos at times, but the teacher would learn with the students. It is really just a logistical problem - how to keep 5 teams busy on different aspects of the problem.

A minor thought is to examine the ETV film distribution system. We have not yet been able to get "The Restless Earth". It and "The Turbulent Ocean", and probably some others should be readily available to a school.

7. Whatever the scope of the final products some years hence that come out of this effort, they will be a vast improvement over the present 'bandaid' approach that is being taken by the profession (education) and the publishing companies in regard to this area. A film here, a brief chapter there, almost no practical way to involve youngsters in activities related to the concepts contained with plate tectonics is unfortunately the present state of the art. The final products, if I may use such a term, should without exception be subject matter sound, activity oriented, student centered, involve simple materials, be directed at various levels of students, be varied, that is utilize a number of different media and techniques to allow the student alternatives by which he or she can attain the desired understandings and attitudes, and above all be useable!

8. For the past three years, I have been giving a one week course to students at O'Connell High School in Arlington. I find their response to this case history method enthusiastic.

9. On item two, I have been busy cutting up maps of the Gulf Coast along various tectonic, stratigraphic, and particularly "salt" lines. I then try to fit the pieces back together into a sensible pattern. I suppose this might somehow be adapted to a series of sheets the students could cut out and work with, but I am reluctant to say how valuable this would prove to be.

10. In appearance before many graduate and undergraduate groups during the past two years, Arthur has found that many, perhaps most, have never heard any postulate of earth dynamics other than plate tectonics. This is a grave indictment of pre-college and most college instruction. Our responsibility to teachers at all levels, and to

geology as a science, is to instill the basic principle of an open, critical spirit of inquiry rather than faith in, and promulgation of, an alleged oracle. Progress in any phase or field of science depends on relentless critical inquiry.

Without detracting from the very significant additions physical oceanography and the postulate of plate tectonics have made to geology, my chief concern is far less with the postulate than with the presumptive omniscience and arrogance of the postulate's adherents and with its passive acceptance by the teaching profession, pre-college, college, and graduate. Without advocating that anyone be invited to rant against plate tectonics at the conference, I do insist that the major emphasis and critique of teaching materials and curricula be placed on the sine qua non of science - the spirit of critical inquiry.

11. To quote Dr. Harold Grad in his famous paper on the magnetic properties of a contained plasma, "A hypothesis that is appealing for its unity or simplicity acts as a filter, accepting reinforcement with ease but tending to reject evidence that does not seem to fit."

As a result of this, the large number of earth-science textbooks that have appeared in recent months are beginning to be overwhelming. They accept the new global tectonics blindly, and do not teach the undergraduate sufficient discernment and discrimination among hypotheses. In fact, they offer no alternatives or alternates.

Therefore, I have been extremely discouraged with the attitudes developed in many universities and particularly as a result of current textbooks. I hope that this conference will do something to remedy the situation.

APPENDIX C

EXAMPLE OF A MODEL LESSON MODULE, "THE SPREADING SEA FLOOR."

The following activity is illustrative of the type of investigation or lesson that can be developed in the Crustal Evolution Teacher Activities Notebook.

This example was developed by Dr. Robert Ridky of the University of Maryland and is currently being used in the New York State Earth Science Curriculum, predominantly at the ninth grade level.

It is suggested that this laboratory investigation takes two 45 minute periods.

THE SPREADING SEA FLOOR

STUDENTS' COPY

QUESTION:

What evidence suggests major changes in the earth's crust?

INTRODUCTION:

When molten volcanic rocks cool and solidify, the magnetic minerals in them are magnetized in the direction of the earth's magnetic field. They retain that magnetism, thus serving as permanent magnetic memories (much like the magnetic memory elements of a computer) of the direction of the earth's field in the place and at the time they solidified.

In 1906, the French physicist, Bernard Brunhes, found some volcanic rocks that were magnetized, not in the direction of the earth's present field, but in exactly the opposite direction. Brunhes concluded that the field must have reversed. Although his observations and conclusions were accepted by some later workers, the concept of reversals in the earth's magnetic field attracted little attention. In the past few years, however, it has been definitely established that the earth's magnetic field has two stable states; it can point either toward the North Pole, as it does today, or toward the South Pole, and it has repeatedly alternated between the two orientations.

Using a combination of magnetic reversal and atomic dating, we shall attempt to make a model of the earth's floating crust. The rift in the Mid-Atlantic Ranges seems to be a place of upwelling so we will concentrate on it. The research vessel *Chain* of the Woods Hole Oceanographic Institute made crossings of the Mid-Atlantic Ridge in 1966, using an instrument which shows intensity and direction of the magnetic field produced by the rock on the ocean floor. The profiles produced by the *Chain* are shown in Figure 1.

Using radioactive dating techniques (principally potassium-argon), volcanic rocks of the ocean floor in this area were given specific ages. The rock ages are shown in Figure 2.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. interpret evidence that suggests that at least portions of the earth's crust are mobile.

2. given appropriate data, determine a rate of movement of a crustal area.

METHOD:

1. Draw a single vertical line through the first peaks to the west of the main rift in the magnetic profile (Figure 1). Read the distance from the main rift on the scale at the bottom of the page (1 mm. = 2 km.), and record it in the data table below.

PEAK NUMBER	1	2	3	4	5	6
Distance West (km.)						
Distance East (km.)						
Average Distance (km.)						
Age from Scale (million years)						
Rate of Movement (cm./yr.)						

2. Repeat step 1 for each set of peaks you see to the west of the rift, and record under 2, 3, 4, 5, 6.

3. Repeat for each set of peaks east of the rift and record under 1, 2, 3, 4, 5, 6.

4. Find the average distance from the Mid-Atlantic Ridge to each magnetic peak.

5. Using the Time Scale (Figure 2), find the age of the rock at each average distance. Record it on the chart.

6. Assuming that the rock has moved from the central ridge, calculate how many cm./year it moved and complete Chart A.

KEY WORDS:

Magnetic field	Geosynclinal theory	Radioactive dating
Upwelling	Mid-Atlantic Ridge	Potassium-argon
Polarity reversal		

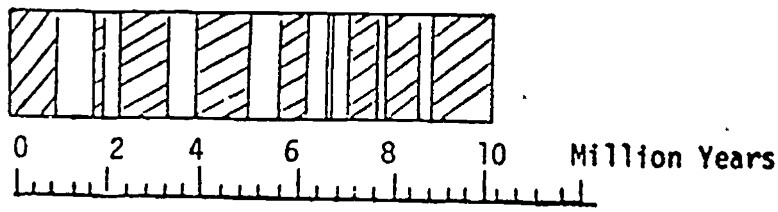
QUESTIONS:

1. Describe the age of the nonsedimentary rock found near the oceanic ridge relative to that found farther from the ridge.

2. Draw a line that represents the amount of movement which occurs on one side of the Mid-Atlantic Ridge in one year.

3. If the distance from Africa to the Ridge is 2400 km., how long ago was Africa over the ridge?

4. Below is a Polarity Reversal Time Scale devised by scientists. Does the polarity of your calculated model correspond to this at all points? (Lined areas are Normal Polarity; white areas are Reversed Polarity.)



5. Explain in your own words how the work you have done in this lab could lead you to believe in a floating crust theory.

TEACHER'S GUIDE

THE SPREADING SEA FLOOR

QUESTION:

What evidence suggests major changes in the earth's crust?

MATERIALS:

Student sheet and Supplementary Sheet.

SUGGESTED APPROACH:

1. Discuss with the students the concept of a magnetic field and the meaning of a magnetic field reversal. Ask how a magnetic field might be "preserved" in molten rock as it solidifies.

2. After making certain that the students understand the method, this exercise can best be done as a homework assignment.

3. After completion of the assignment, discuss with the students:

   A. The meaning of ocean floor spreading.

   B. The rate at which it is thought to be occurring.

   C. How does it relate to other theories such as the geosyncline theory and the continental drift theory.

PRECAUTIONS:

1. Students sometimes have difficulty realizing that the upwelling occurs along the mid-Atlantic Ridge and spills over in both east and west directions. Therefore, materials of similar age should be located at approximately equal distances east and west of the ridge. The magnetic reversal pattern serves only to identify rock units of the same age.

2. As in most natural systems, the movement has not been perfectly symetrical, the distance the rock has drifted eastward is consistantly less than the distance it has moved westward, therefore an average must be taken and used for computation.

TYPICAL RESULTS:

NUMBER	1	2	3	4	5	6
Distance West (km.)	40	70	80	104	118	134
Distance East (km.)	28	42	60	74	90	102
Average Distance (km.)	34	56	70	89	104	118
Age From Scale(million yrs.)	2.8	4.4	5.6	7.1	8.4	9.5
Rate of Movement (cm./yr.)	1.21	1.24	1.24	1.25	1.24	1.23

The line drawn by the student for question 1 should be about 1.2 cm. long. Africa should have been in the indicated position (question 2) about 2.0 X 10^8 years ago,

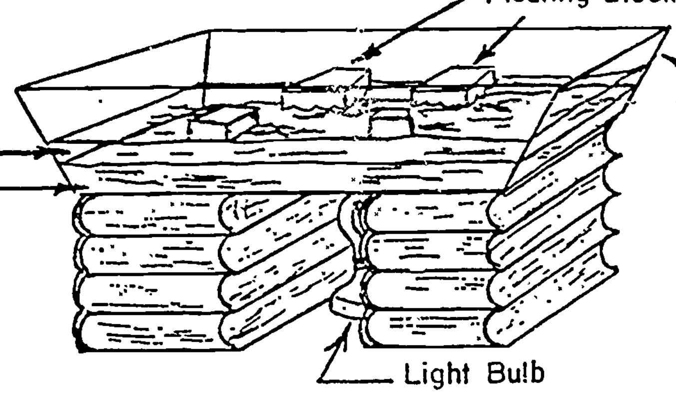
$$\frac{2.4 \times 10^3 \text{ km.}}{1.2 \frac{\text{cm.}}{\text{yr.}}} \times \frac{10^5 \text{ cm.}}{\text{km.}} = 2.0 \times 10^8 \text{ years.}$$

For question 3, correspondence should be excellent at all points used in calculation. Short intervals may not show up on the general profile because of the amount of material magnetized and the lack of sensitivity of the instrument.

MODIFICATIONS:

Sea floor spreading and the Continental Drift Theory can be demonstrated by using the following technique.

1. Set up the apparatus as shown below.



Note: Pour the lighter fluid very slowly, using a piece of cardboard to break its velocity. Try to maintain a sharp interface between the more dense (dark fluid) and the less dense (light fluid). Density of the fluids can be controlled by storing the dark fluid in the refrigerator and the light fluid in a bucket of warm water, previous to class time.

2. Place a transparent lid on the box with a plastic sheet attached to it and sketch the position of the "continents" as they appear before the light is turned on.

3. Observe the light and dark fluids from the side of the shoe box and sketch the interface between the two.

4. Turn on the light and observe both the interface between the two fluids and the position of the paraffin blocks. Make sketches of each at 5-minute intervals for a period of 20 minutes.

5. Relate what you have seen to continental drift and sea floor spreading.

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Samuel W. Matthews & Robert F. Sisson, "Science Explores the Monsoon Sea," *National Geographic*, Oct. 1967, Vol. 132:4, pp. 554-575

J.D. Phillips, "Magnetic Abnormalities over the Mid-Atlantic Range Near 27°N," *Science*, Aug. 25, 1967, Vol. 157, pp. 920-922

W.C. Pitman, III, & J.R. Heirtzler, *Science*, Vol. 154, 1966, p. 1164

SUPPLEMENTARY SHEET

FIGURE 1: ROCK POLARITY ACROSS THE ATLANTIC

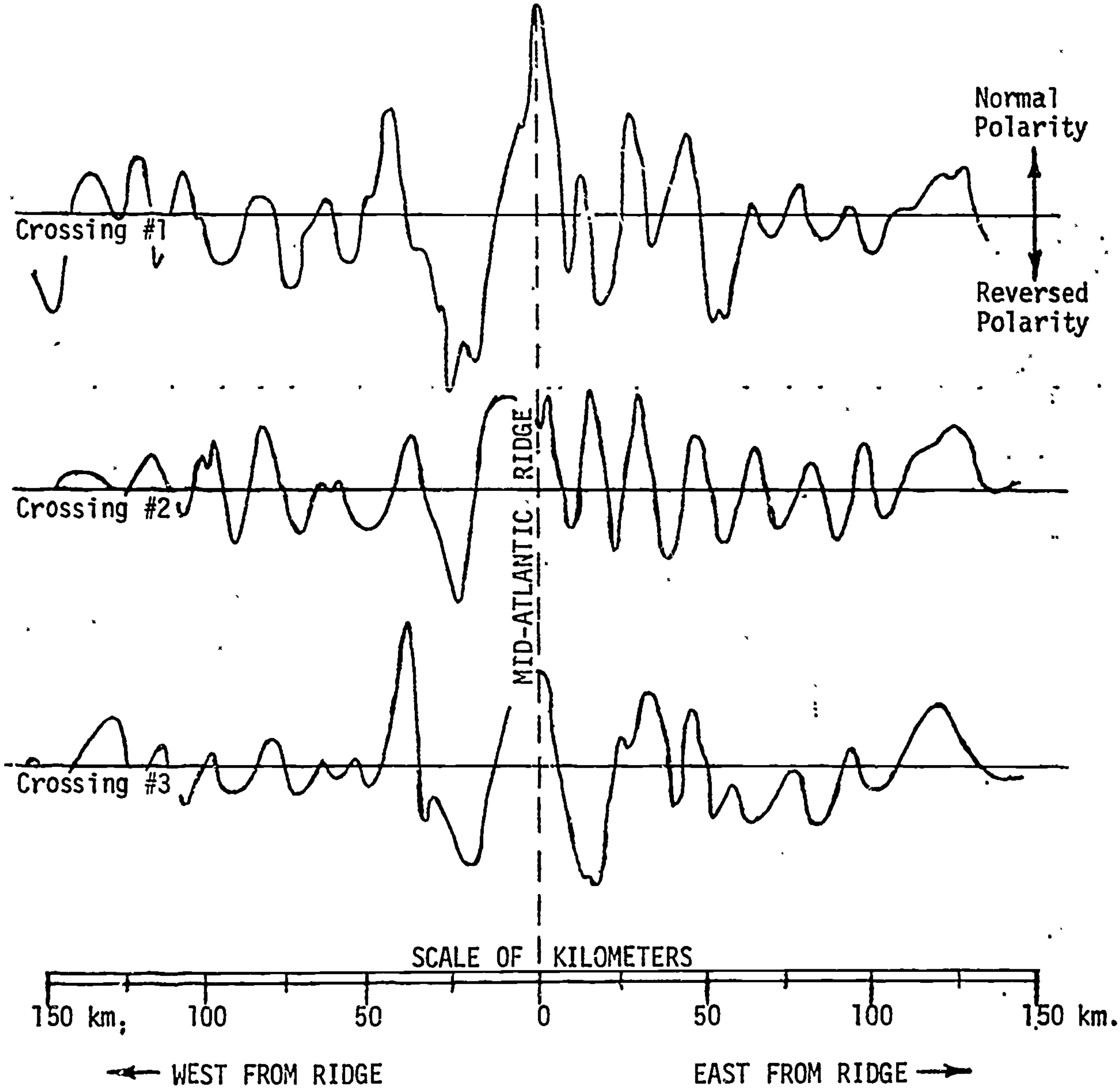
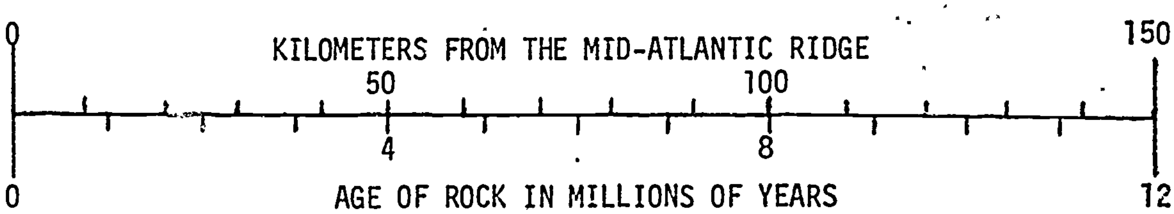


FIGURE 2: ROCK AGE DETERMINATION SCALE



APPENDIX D

LIST OF SUGGESTED TOPICS FOR LESSONS AND/OR ACTIVITIES

I. Topography

A) mid-ocean ridge
B) trenches/island arcs
C) boundaries of translation (San Andreas fault)

II. Seismicity

A) mid-ocean ridge
B) trenches/island arcs
C) boundaries of translation (San Andreas fault)
D) relevance to earthquake prediction
E) earthquake hazard reduction with reference to man

III. Sediment distribution age (rates of spreading)

A) mid-ocean ridge
B) trenches/island arcs
C) boundaries of translation (San Andreas fault)
D) Paleocirculation

IV. Magnetic anomalies

A) mid-ocean ridge
B) trenches/island arcs
C) to identify displacement

V. Volcanicity and heat distribution

A) mid-ocean ridge
B) trenches/island arcs
C) boundaries of translation (e.g. Line Islands)
D) relevance to man through ore deposit sites and geologic hazards
E) relevance to geothermal resources
F) relevance to volcanic prediction

VI. Rates of motion (activity)

VII. Fossil record development for:

A) correlation of sediments and environments
B) tectonism
C) ocean paleoenvironments and climate

VIII. Possible driving mechanisms (investigation)

IX. Relevance to man

A) natural resources
  1. distribution of ore deposits correlating with:
    a) volcanism on land
    b) seismicity on land
    c) mountain building sites
    d) volcanism at ridges
  2. economic deposits of Continental Margins
    a) oil and gas deposits
    b) salt deposits
  3. geothermal resources
    a) selected sites
      i) oceanic - islands and ridges
      ii) heating of homes - Rejkjavik, Iceland
      iii) continental - California, Oregon, New Zealand

X. Zoogeographic distribution of plants and animals

XI. Paleogeographic distribution of glaciers, coal beds, and evaporites

APPENDIX E

CONTENTS OF PROPOSED TEACHER RESOURCE BOOK

I. A discussion or treatment of crustal evolution. 50 p. ±

A) Relevancy in classroom

B) History)
(Can be combined
C) Methodology)

D) Global view of earth features and properties (and with geologic time)

1. topography
2. seismicity patterns (plate mosaic)
3. volcanicity
4. sediments

E) Plate tectonic hypotheses

1. definition of plate
2. data constraints
3. assumptions
4. testing of hypotheses

F) Plate characteristics

1. boundaries
   a) divergent spreading centers
   b) convergent margins
   c) boundaries of translation
2. within plates
3. plate motion
4. driving mechanisms

G) Geologic record

1. fossil record development
2. correlation of sediments
3. paleooceanography and climatology
4. mountain ranges
5. evidence for post-Paleozoic plate distributions
6. evidence for Paleozoic and earlier activity (strong emphasis on Eastern North America, Western Europe and West Africa)

H) Relevance to man

1. natural resources
   a) deep ocean floor
      i) Mn nodules
      ii) metalliferous deposits (e.g. Red Sea; Mid-ocean ridges)

b) continental margins
  i) oil and gas
  ii) Phosphorite
  iii) Evaporite (salt)
  iv) Limestone
  v) geothermal resources
c) convergent boundaries
  i) metalliferous deposits (e.g. Cu deposits in Andes)

2. socio-economic implications
  a) earthquake and volcanic prediction
  b) geographic distribution of earthquakes and volcanoes
  c) earthquake and volcanic hazard reduction
  d) climatic prediction from sedimentary record of ocean
  e) zoogeographic distribution of plants and animals
  f) effect of plate migration on oceanic circulation and resulting phenomena (upwelling, etc.)
  g) long term implications of plate migrations (glaciation)

I) Summary