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Board on Earth Sciences
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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INTRODUCTION

The concept of a National Continental Scientific Drilling Program has been the subject of numerous reports over the last decade [e.g., Continental Drilling (Shoemaker, 1975), Continental Scientific Drilling Program (U.S. Geodynamics Committee, 1979), and Opportunities for Research in the Geological Sciences (Board on Earth Sciences, 1983)] and has now matured to the point at which a deep drill hole dedicated to testing a fundamental geological hypothesis is being seriously considered. A large number of fascinating continental crustal problems over a wide range of geological disciplines have been proposed for testing by the drill, and many sites at which these tests could be made have been suggested in the first two of the above-cited reports. As the prospect for funding of an initial dedicated hole has brightened, attention has focused on the necessity of setting priorities among the various experiments and sites that have been proposed. Panels of the Continental Scientific Drilling Committee (CSDC) have over the last four years been involved in establishing priorities within the areas for which they have responsibility: thermal regimes, basement structure and deep continental basins, active fault zones and downhole measurements, and mineral resources.

At the same time, the CSDC Panel on Drilling, Logging, and Instrument Technology was evaluating the technical readiness to perform proposed drilling experiments. The

CSDC Panel on Sample Curation and Data Management is developing a plan for handling samples and data from continental scientific drilling as a national resource.

At a meeting of the CSDC with representatives of its panels in November 1983, the committee addressed an evaluation of the high-priority experiments and sites brought forward by each panel. These high-priority projects were evaluated against the standards of scientific significance, existing data base, and availability of existing drilling, logging, and downhole measurement technology. Under these constraints the CSDC determined that (a) a continuing National Program of Continental Scientific Drilling is required, extending over a period of decades and dealing with a variety of critical problems in continental crustal structure, development, and tectonics as improvements in technology make them feasible and when the drill as a research tool is indicated; and (b) the experiment with highest immediate priority is a dedicated research hole in the Southern Appalachians to test the "thin-skinned tectonics" model of crustal structure. It was also agreed that the CSDC should be alert to any opportunities to conduct investigations added on to current and planned drilling activities, but priorities for such opportunities cannot be established in advance.

The purpose of this report is to provide a brief account of the high-priority objectives for a national program of continental drilling for scientific purposes that have been determined by the CSDC and its subject panels. From these major objectives, the committee has recommended that the first project that should be addressed in what is expected to be a long-term and scientifically rewarding program. More detailed reports discussing the rationale for selection of high-priority objectives for each of the subject panels are in the final stages of preparation by the CSDC and will be issued later in 1984.

SETTING PRIORITIES

Information provided by the Panel on Drilling, Logging, and Instrument Technology and presented at the 1983 Sandia National Laboratories Workshop on Borehole Measurements and Interpretation in Scientific Drilling (Cooper and Traeger, 1984) indicated that logging and coring equipment dependent on silicon chips, elastomeric seals, and electric cables cannot be relied on in temperature regimes that exceed about 275°C and that few if any instruments could withstand waters rich in hydrogen sulfide. These constraints suggested that the first dedicated drilling experiments should be into locations that are unlikely to be characterized by such hostile environments--locations that could be drilled with standard drilling, coring, and logging equipment that has been thoroughly tested and is in regular use.

The priority sites in active hydrothermal-magma systems recommended by the Panel on Thermal Regimes all carry with them, if one is to reach the targets of greatest scientific interest, the strong probability of encountering thermally or chemically hostile environments. Thus, while the CSDC recommends that shallow and intermediate-depth drilling should be continued at these sites in order to define more sharply the questions to be addressed through deep drilling, we recognize that considerable technological development will have to precede a deep hole at any of the research targets under consideration. Advanced development of tools and instruments to withstand high-temperature drill-hole environments is currently being conducted by industry and government laboratories and will be followed closely by the CSDC.

The Panel on Active Fault Zones and Downhole Measurements presented as high-priority experiments several drill sites at which it would be possible to drill through or into active fault zones. Each of the general sites proposed appeared to offer relatively high risk of hole instability and a significant chance for loss of hole or loss of circulation in severely fractured rock. It was concluded that the research drilling program should develop experience in less difficult areas before attempting dedicated deep drilling in an active fault zone. Holes drilled by the petroleum industry that are close to or penetrate active fault zones may present opportunities for add-on investigations if some of the particularly significant holes, along with relevant downhole data, are made available for this purpose.

The objectives accorded high priority by the Panel on Mineral Resources are the roots of cold or fossil hydrothermal, ore-bearing systems that provide opportunities to study important problems that can be solved only by investigations with the drill. The possible physical connection between shallow epithermal ore deposits and deeper mesothermal deposits is untested and represents an objective of both scientific and economic significance. It was concluded by the CSDC that although drilling targets into these systems were exciting and technically feasible, their restricted size and shape make them more difficult to define than the targets suggested by the Panel on Basement Structures and Deep Continental Basins (below). Additional detailed geological and geophysical surveying is necessary before a drilling project at a particular mineral resource site is mounted.

The Panel on Basement Structures and Deep Continental Basins proposed a series of experiments that involve features that tend to be horizontally oriented and of great lateral extent so that even at considerable depths they present targets that could be easily intersected. Several of the targets accorded high scientific interest, such as layered structures suggested by seismic-reflection profile lines recorded throughout the United States, occur at depths so great as to offer great technical difficulty for an initial dedicated hole. First priority among the targets proposed by the panel, and the highest priority accorded by the CSDC among all the experiments proposed, is a drilling project to test the thin-skinned tectonic thrusting model for the Southern Appalachians structure.

HIGHEST-PRIORITY TARGET

The Appalachians represent a cradle of fundamental concepts in crustal geology in the United States. In the Southern Appalachians, interpretation of deep seismic-reflection profiling data indicates the presence of far-traveled allochthonous thrust sheets above autochthonous/parautochthonous rocks, which themselves overlie older basement. Many recent geological and geophysical studies indicate that Paleozoic sedimentary rocks of the Valley and Ridge Province can be traced from their near-surface position on the west for large distances, perhaps several hundreds of kilometers, beneath the crystalline and generally older rocks of the Blue Ridge and Piedmont Provinces, and perhaps beneath the Coastal Plain Province.

The hypothesis to be tested is that of thin-skinned thrusting of crystalline rocks in the Appalachian orogen. This concept is important scientifically for two reasons that go beyond the bounds of Appalachian geology. First, the thrusting can be explained as a result of the final closing of the proto-Atlantic Ocean. Hence the thin-skinned thrusting that is likely the dominant process in the formation of the huge Appalachian orogen can be explained as a natural consequence of the theory of plate tectonics. If so, an extremely important step has been taken, because plate tectonics to date, for all its importance in explaining the dynamics of the ocean basins and the movement of continents as entities, has not provided satisfying explanations for much of internal continental geology. Second, the Appalachian orogenic belt is thought to be a type example for many orogenic belts of different ages and in different parts of the world. Thus, the understanding of the Appalachian story probably will have profound and widespread implications. In fact the currently evolving story of the accreted terranes that make up huge land masses such as Alaska, mainland China, and the Western United States and Canada may be an expression of the same, or closely related, processes. The tremendous significance of the Appalachian thin-skinned thrusting problem thus cannot be denied.

The critical test of this hypothesis to be supplied by drilling is simple and straightforward. Drill a hole to a depth of about 10 km through the thrust sheets at some distance back from their forward edges and determine whether sedimentary or metasedimentary Paleozoic rocks correlatable with those to the west are encountered below. If so, the thrusting hypothesis must be correct. That test is the prime objective of this hole.

This research drilling will also test a number of other features of lesser but still fundamental significance. For example, details of deformation in the thrust sheet caused by its movement are important. The degree of metamorphism and other characteristics of the buried sedimentary rocks are important scientifically and also practically for what they tell us about the thermal history of the large volume of unexplored sedimentary rocks apparently buried beneath the crystalline rocks, thus having a direct bearing on exploration for petroleum resources in parts of this and other overthrust terranes. Information on fluids trapped or having escaped from the sedimentary rocks is also of both fundamental and practical significance, both in understanding the mechanics of fault movement and in connection with possible ore formation and mineral transport. An Appalachian hole is also an appropriate place for testing and development of new drilling and logging techniques and for a wide variety of in-situ measurements of rock properties and other parameters of the deep crust. And, of course, there is the theme of exploration of the unknown. What, indeed, are conditions like at great depths, what are they like below the buried sediments, and what kinds of rocks are located there?

The general location of the recommended Southern Appalachian deep research hole is agreed on, but special studies of the area must be made in considerable detail before the specific site is determined. Scientists with the most thorough knowledge of Appalachian geology and geophysics and of drilling and logistical problems must be consulted. Further detailed geological, geophysical, and geochemical surveys are required, and additional regional surveys such as further long-line seismic-reflection profiling would be of value. However, the purpose for a predrilling survey is to ensure that a suitable site for the main drilling experiment is identified. Once that has been ascertained, drilling should begin. Additional studies may well continue to focus better the contemplated in-hole investigations and to provide the best possible regional framework for interpretation. In this way drilling and comcomitant studies become complementary and interactive.

The CSDC has not designed nor set criteria for such surveys, but it draws attention to them as an absolutely necessary component of the drilling program. Funding for the drilling program must include the cost of such surveys, as well as adequate sums to support analysis of the samples and information obtained in drilling and to support other reasonable experiments to be carried out in the hole or in relation to the overall effort.

CONCLUSION

The two reports, Continental Drilling and Continental Scientific Drilling Program, form a basis for this report and provide comprehensive discussions of the subject of continental drilling for scientific purposes in a number of research areas. The purpose of this report is to present a specific recommendation of the Continental Scientific Drilling Committee on where the first deep hole dedicated to scientific exploration of the continental crust in the United States should be located. The most accessible and feasible hypothesis to test is the one of thin-skinned tectonics; the southern Appalachians, where the thrusting of crystalline rocks of the Blue Ridge and Piedmont Provinces over early Paleozoic sedimentary rocks is postulated, represents the best location for this drilling project. This hypothesis is of fundamental importance to the understanding of the evolution of continents.

Funding for this project must include, in addition to costs for actual drilling, support for necessary preliminary site surveys and for collection and analysis of scientific samples and other data from the drill hole.

Finally, we reiterate the point that this project represents the first hole in what will become a national program of continental drilling for scientific purposes. The scientific community is invited to participate in this program by identifying questions and problems and proposing projects to find solutions concerning the properties, dynamics, and evolution of the continental crust that require data that can be obtained only by the drill.

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