public, for whom they form a greatly appreciated pleasure ground, though their primary function is the growing of as large a collection of plants as possible for scientific study. The gardens cover some 300 acres along the south bank of the Thames between Kew and Richmond, the western half corresponding to part of the garden of Richmond House, and the eastern half, to the grounds of Kew House. The site is flat, and such elevations and depressions as now exist are all man-made; the poor and shallow soil overlies river gravel, and atmospheric pollution is high, discouraging the growth of many conifers. Despite these disadvantages, deciduous trees and shrubs grow splendidly. The extensive collection of these trees and shrubs is arranged for the most part according to plant families. Through skillful landscaping the grounds present a diversified aspect, and the monotony which one might expect to find where so many trees and shrubs are grown on a flat terrain has been avoided through the construction of such features as long grassy vistas, winding paths, and curved borders; the artificial lake and the pond; and buildings such as the greenhouses (notably the Palm House and the Temperate House) and the Pagoda. Another device which helps to make the gardens attractive to visitors is the bold planting of a single genus, which provides a great display of color at some period of the year. Thus, in early spring, drifts of daffodils and crocuses and groups of blossoming Japanese cherries are special features; shortly afterwards a large group of *Malus floribunda* comes into bloom. In May, Kew is visited by thousands of people who come to see the great sheets of bluebells which carpet the woodland. Different varieties of lilac are planted together to provide a mass of color, as are varieties of azalea, while the planting of rhododendrons, known as "rhododendron dell," is a special attraction, and so too in their season are the iris and rose gardens. In addition to the trees and shrubs, a vast collection of herbaceous plants is grown out-of-doors, in the herbaceous ground, the rock garden, and the aquatic garden. And finally, the five acres of greenhouses hold a large collection of plants which do not thrive out-of-doors at Kew and for which temperatures ranging from those of cool temperate zones to those of the hottest tropics are provided.

The beginning of the third century of its existence sees the Royal Gardens bigger and better equipped than at any previous time in its history, and it has never been more active in both the horticultural and the botanical spheres. There need be no doubt that the Kew tradition will be worthily maintained in the future and that Kew will continue to be a mecca for botanists and horticulturists alike.

The Earth's Mantle

Its nature may be directly discovered by drilling in ocean basins where the overlying crust is thin.

Gordon G. Lill and Arthur E. Maxwell

There are several ways to determine the nature of the earth's mantle, but in the last analysis only the direct method will be satisfactory. We must drill down to the mantle and bring up as much sample as possible for examination. We then will know what the mantle is like, at least at that one particular spot.

In February of 1957, the American Miscellaneous Society (AMSOC), an esoteric organization with branches throughout the United States and in some foreign countries, was approached by Walter Munk of the Scripps Institution of Oceanography, who represented, as well, Harry Hess of Princeton University. Munk's proposition was that the society should undertake the promotion of a deep drilling project designed to bore through the earth's crust and bring up a sample of the mantle. The matter was argued from the patio of Munk's home, onto the campus of the Scripps Institution of Oceanography, and into the dinner hour and beyond at the home of Roger Revelle. The outcome was inevitable. The proposal was reasonable, the idea was exciting, and there were plenty of excellent scientific reasons for undertaking the work.

With funds granted by the National Science Foundation, the AMSOC Committee of the National Academy of Sciences–National Research Council was organized to place the project on a firm scientific basis. The committee is composed of the following members: Gordon G. Lill (chairman), Willard Bascom (executive secretary), George Colchagoff, Maurice Ewing, William B. Heroy, Harry Hess, Harry Ladd, A. E. Maxwell, John Mecom, Walter Munk, Roger R. Revelle, William Rubey, J. I. Tracey, and Leonard Wilson.

The pros and cons of the project were argued again at a special meeting of the Division of Earth Sciences of the National Academy of Sciences–National Research Council in late April of 1958. The arguments presented against the project were as follows: (i) The cost will be so great that funds will be drained from other worth-while work in the earth sciences. (ii) One hole will not suffice. Since the mantle is not homogeneous, it will be necessary to drill many holes to determine its nature. In this case, drilling costs will become prohibitive. (iii) It is known from geochemical experiments that a phase change occurs in the physical nature of rocks under the conditions of pressure and temperature which must exist in the region of the Mohorovicic Discontinuity. (iv) It is known from laboratory experiments that the mantle is composed of peridotite, eclogite, or dunite. (v) The publicity given large projects is bad for science.

So far as we can remember, these were the major arguments against the

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project presented at the meeting. They are reasonable arguments, and because of them the project will not be undertaken in haste, despite the fact that some might consider its beginnings to have been precipitate. The arguments for the project, which has somehow survived the onslaught of scientific disagreements, are presented in this article.

International Aspects of Deep Drilling

There is intensive international competition in science these days which is a kind of substitute for war. It pervades all areas of science.

At the 11th general assembly of the International Union of Geodesy and Geophysics (UGGI), held in Toronto in September 1957, a resolution was introduced by the United States representatives which we quote here, since it has not received much notice.

> "*Considering* that the composition of the Earth's mantle below the Mohorovicic Discontinuity is one of the most important unsolved problems of geophysics; and that, although seismic, gravity and magnetic observations have given significant indications of the nature of this material, actual samples that could be examined petrographically, physically and chemically are essential; and that modern techniques of drilling deep wells are rapidly developing to the point where drilling a hole 10 to 15 km deep on an oceanic island may well be feasible; and that the crustal material above the Mohorovicic Discontinuity is also of prime interest; The IUGG urges the nations of the world and especially those experienced in deep drilling to study the feasibility and cost of an attempt to drill to the Mohorovicic Discontinuity at a place where it approaches the surface."

At the meeting, Russian representatives heartily endorsed the resolution and announced that they had the equipment and capability to do the job. Subsequently the Soviet Academy of Sciences established a new branch in Novosibirsk, headed by Mikail A. Lavrentyev. Lavrentyev's group was set up to solve the problems of deep drilling. One may surmise that the Soviets also intend to drill to the mantle. It would give them great pleasure to beat the United States in this undertaking, since drilling is a field in which we are considered to be proficient.

We hear, also, rumblings from the direction of Great Britain. The British, too, have something to contribute to deep drilling and may well undertake a project of this sort.

The Earth's Interior

Students of the earth have always speculated on the nature of its interior. At present nearly all geophysicists agree that structurally the earth consists of a crust, mantle, core, and inner core. On the continents the crust is differentiated into the lighter granitic rocks and the heavier basaltic rocks. The basalt is considered by some to lie beneath the granite. Here and there basalt appears on the surface, having emanated from fissures or volcanoes. Under the oceans, the granitic rocks are missing. Below the crust, the mantle extends to the core to a depth approximately one-half the earth's radius. Bullen (*1*) gives the evidence for an inner core; this theory, until a short while ago, was controversial but now is accepted. These divisions of the earth's interior are often referred to as "layers," and this is misleading. The term should be dropped.

Bullard (*2*) and Byerly (*3*) have both made excellent summaries of the seismological evidence relative to subcontinental structure; they find it to be generally agreed that the Mohorovicic Discontinuity, the assumed boundary between the crust and mantle, is about 35 kilometers below the continents. Just below this discontinuity the velocity of the longitudinal elastic waves increases nearly everywhere to about 8 km/sec. Since the depth to the mantle under the continents is so great, it is not likely that we will be able to obtain samples there.

On the other hand, from the recent marine seismic work of Ewing (*4*), Hersey (*5*), and their associates, in the Atlantic, and from that of Raitt and his associates (*6, 7*), in the Pacific, we find that there is a different situation under the oceans. Raitt (*7*) has shown in his studies of Eniwetok Atoll that the depth to the mantle under that structure is approximately 16 to 17 kilometers; also, in an earlier paper Raitt (*6*) reports that the mantle under the Pacific Basin in the central equatorial Pacific lies at depths of as little as 5 to 7 kilometers below the ocean bottom. Raitt (*8*) has mentioned that the Mohorovicic Discontinuity just to the north of Fiji lies particularly close to the ocean floor—less than 5 kilometers below it. Ewing and Worzel (*4*) have shown that the mantle under the Atlantic Basin lies at a general depth of 9 to 10 kilometers below the bottom, while Hersey (*5*) has speculated that the mantle may be at the same depth under the Bahamas as under the Blake Plateau—about 10 kilometers below the ocean floor.

From the fact that the seismic velocity of longitudinal elastic waves seems to be about the same under the oceans as under the continents, it could be deduced that the mantle is more or less homogeneous. Mason (*9*), in summarizing the laboratory studies of various workers on the elasticity of rocks, finds that the mantle may consist of any or all of three types of rocks: dunite (olivine), peridotite (olivine and pyroxene), and eclogite (garnet and pyroxene). These rocks give the required seismic velocity in the laboratory, and since they are ultrabasic, it could be concluded that the mantle may be homogeneous with respect to the family of rocks which compose it.

Other investigations indicate that the mantle may not have the same composition everywhere as that indicated above. Bullard, Maxwell, and Revelle (*10*) have shown that the heat flow through the deep-sea floor is about the same as through the continents—that is, about 1.2 $\mu cal/cm^2$ sec. Since the continental crust is known to contain large quantities of radioactive material which can account for the heat flow there, and the thin crust under the ocean floor has no such radioactive granitic material, it is suggested that a difference in physical or chemical characteristics exists between the mantle under the oceans and the mantle under the continents.

The question as to whether the Mohorovicic Discontinuity is evidence of chemical changes in the rocks of the crust and mantle or only of a physical phase change is still unanswered. Lovering (*11*) cites recent evidence in favor of the phase change, suggesting that the Mohorovicic Discontinuity results from conditions of temperature and pressure which cause the transformation of a basalt crust into an eclogite mantle. Using the average for crustal thicknesses beneath the continents and oceans and assuming that the heat flow is similar in the two locations, he has derived the relation illustrated by the dashed line in Fig. 1. However, recent seismic and geothermal results (*6, 10*) from the Pacific, which are also shown in Fig. 1, tend to controvert this idea. They indicate temperatures at the Mohorovicic Discontinuity that are far in excess of those assumed by Lovering. The question of whether the discontinuity represents a chemical change or a physical change is still unsolved.

There are other varied and enormous problems associated with the earth's interior. Is the material of the mantle strong enough to support, over long periods of time, loads of the size of island chains, as discussed by Hess (*12*)? Is the material in the mantle capable of sustaining convection currents over the long periods of time required for the world-wide geologic processes of continental growth and associated orogeny, as proposed by many writers on the subject? Vening-Meinesz *et al.* (*13*) have proposed the existence of convection currents in the mantle to account for the existence of the deep trenches which are invariably found in association with continents and island arcs. They arrived at the conclusion that such currents exist because they found negative gravity anomalies associated with the trenches. Ewing and Worzel (*4*) believe that the negative gravity values may be accounted for by the light and unconsolidated sediments found in some of the trenches.

From these citations it may be seen that our evidence about the nature of the earth's mantle, even though some of it may be conclusive, is indirect. It is of obvious importance to the progress of the earth sciences that we find means of obtaining direct evidence on the nature of the earth's interior.

Oceanic Sedimentary Section

Some members of the AMSOC Committee believe that the sectioning of sediments at the bottom of the ocean is as important scientifically as all other phases of the drilling program. All agree that it is important and significant.

In the most promising drilling areas there are from 1000 to 3000 feet of sediments overlying the basement rock. In these sediments we will find the compressed, complete history of the ocean basin, whether it be the Atlantic or the Pacific. We will learn about climatic conditions of the past, and changes in atmosphere-ocean balances may be revealed through studies of the carbonate materials.

If the cores can be properly collected we hope to gain knowledge about the circulation of the ancient oceans through studies of bedding and particles. The directions of magnetic fields of the past may be revealed through chemical and orientation studies of the magnetic particles.

It is probable that the deep ocean basins have been a feature of the earth since its beginnings, and age determinations made from a complete oceanic sedimentary section will settle the question once and for all. Age determinations will be made from the fossils and by appropriate physical-chemical methods. There is proof from deep-sea drilling at Eniwetok (*14*) that the sea mount on which the atoll rests is Eocene in age. The Scripps Institution of Oceanography has dredged the tops of sea mounts and found fossil corals of Cretaceous age. Cretaceous fossils have also been obtained by the Lamont Geological Observatory through dredging on the Mid-Atlantic Ridge. All of these determinations may be anomalous in that the dredging and drilling took place in areas where there were islands, sea mounts, and mountain ranges rather than in the deep ocean basins.

Drilling Methods under Consideration

Under the Central Pacific the mantle, at a depth of 5 kilometers below the ocean floor, is well within the reach of present drilling equipment. We have, however, to remember that the Pacific Ocean lies above the sea bottom. Perhaps even this presents no barrier to reaching the mantle by drilling, in view of a recent report in the *Oil and Gas Journal* of 7 October 1958 entitled "Drilling in water up to 1500 feet deep." This report describes *CUSS I* (Continental-Union-Shell-Superior), a 260-foot, 1479-ton Navy freight barge converted for drilling in deep water by these four companies. From *CUSS I* it is possible to drill to depths of 10,000 feet with 4.5-inch drill pipe through water as deep as 1500 feet. A great deal of study will be required, however, before it can be determined whether it will be possible to drill from this or any other barge to 16,000 feet below the sea floor, through water 15,000 to 18,000 feet deep.

It may be necessary to design a completely new drilling barge. Very heavy strings of drill pipe, perhaps 30,000 feet in length, will be required. No barge or platform now in existence is capable of handling the lengths of pipe that will be needed. The drill stem itself must be carefully chosen, since it will undergo

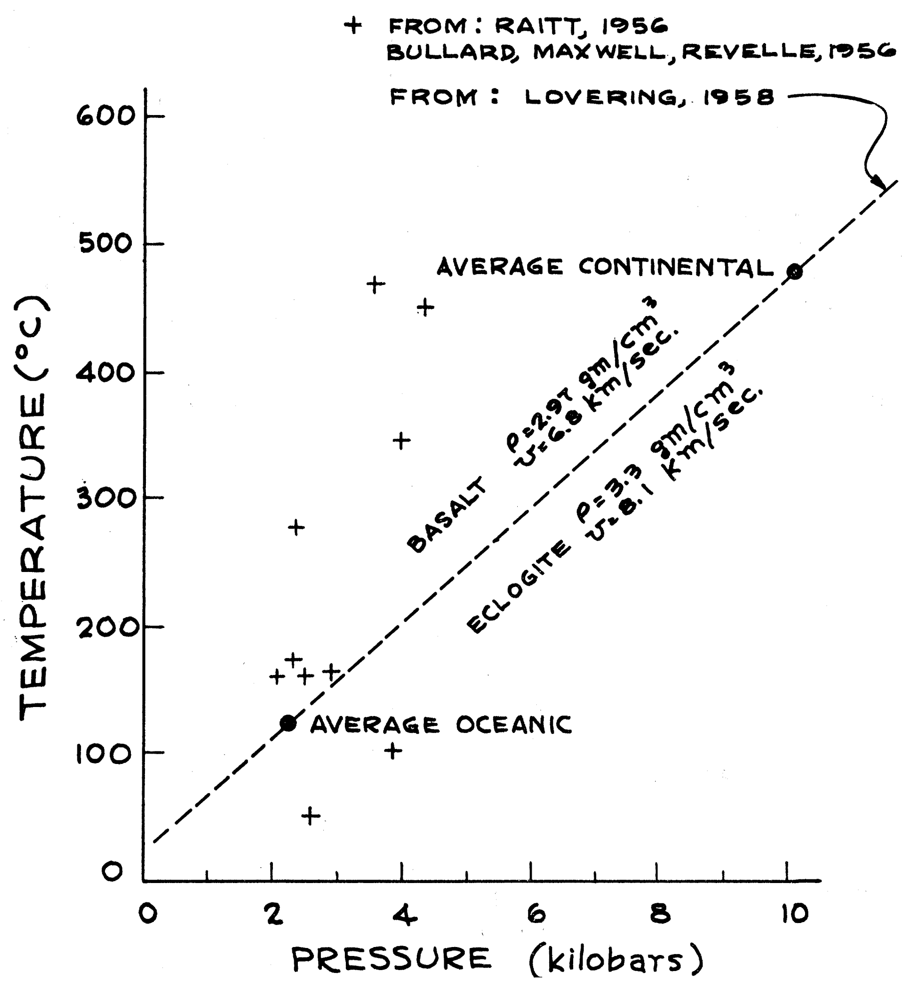

Fig. 1. Relationship of temperature and pressure relative to the Mohorovicic Discontinuity, as suggested by Lovering, and seismic and geothermal data from the Pacific recently reported by Raitt (*6*) and by Bullard *et al.* (*10*).

uncommon stresses and torques. Power supplies must be investigated, because smooth delivery of power will be a necessity. It has been proposed that the power may have to be delivered at the bottom of the ocean rather than from a barge at the surface in order to eliminate the 15,000 to 18,000 feet of drill stem needed to get through the water.

In addition, several kinds of fixed platforms have been proposed, some anchored and some on legs. Most of these appear to be impractical because of the depth of the sea where the drilling is to be done and because of the great cost.

A "Drilling Methods" panel is being organized by the AMSOC Committee to either devise new drilling techniques or determine which of the known techniques can be used.

Choosing the Drilling Site

Choosing the drilling site will be one of the most difficult problems. A panel has been appointed to select the site. Without doubt this will be somewhere in the ocean.

One possible spot for drilling in the Atlantic lies 200 miles north of Puerto Rico on the rise just north of the Puerto Rican Trench. This is a region of hurricanes and of troublesome and little understood oceanic currents. This means, of course, that the weather might be an obstacle in this area.

In the Pacific the depth to the mantle under the Albatross Plateau is not great. This plateau is about 2000 miles southwest of San Diego. Logistic problems alone will probably eliminate this area as a drilling site, since it is necessary that a good supply port be reasonably close at hand. Also, large oceanic swells occur throughout the area. The huge southwest Pacific swells can be as alarming as storm waves.

All promising areas must be investigated with respect to the following factors: (i) The mantle must be within reach; (ii) an adequate sedimentary section must be obtainable; (iii) a good port must be reasonably close at hand; (iv) ocean currents, swell, and depth of water must be suitable; and (v) prevailing weather conditions must be favorable.

An averaging and weighting of the findings on these points will give us our location. A tremendous amount of work must be done. It is readily apparent that it will not be easy to select the site.

Financing

Drilling to the Mohorovicic Discontinuity falls in the category of "big projects." Experience shows that the so-called "big projects," such as moon rocketry, atom bombs, and national observatories, tend to bring money into an entire field of science rather than decrease the amount of funds available for small projects in that field. It is not a question of big projects versus little projects. Each must justify itself.

The Mohorovicic Discontinuity project probably can be accomplished for $5 million. Earlier and larger estimates were out of bounds. Five million dollars is a lot of money, but compared to the many millions of dollars that are being spent on moon rocketry and the billions being spent on atom bombs, this is not an overly ambitious scientific endeavor.

The American Miscellaneous Society, with its flair for seeing the lighter side of heavier problems, likes to quote the following proverbs when discussing the "Moho": (i) "When going ahead in space, it is also important to go back in time"; (ii) "The ocean's bottom is at least as important to us as the moon's behind!" These proverbs derive from modern scientific folklore. The point is, let us first thoroughly examine the earth before we abandon study of it in favor of extraterrestrial problems. In any case, we may consider the earth to be a prototype planet, and from detailed study of the earth we cannot fail to gain information which will be useful to us in studying other planets and the remainder of the universe.

References

1. K. E. Bullen, *Handbuch der Physik* (Springer, Berlin, 1956), vol. XLVII, *Geophysik I.*
2. E. Bullard, in *The Solar System,* G. P. Kuiper, Ed. (Univ. of Chicago Press, 1954), vol. 2.
3. P. Byerly, in *Advances in Geophysics,* H. E. Lansberg, Ed. (Academic Press, New York, 1956), vol. 3.
4. M. Ewing and J. L. Worzel, *Bull. Geol. Soc. Am.* 65 (Feb. 1954).
5. B. Hersey, personal communication (1957).
6. R. Raitt, *Bull. Geol. Soc. Am.* 66 (Dec. 1956).
7. ———, "Seismic Refraction Studies of Eniwetok Atoll," *U.S. Geol. Survey Profess. Paper No. 260-S* (1957).
8. ———, personal communication.
9. B. Mason, in *The Solar System,* G. P. Kuiper, Ed. (Univ. of Chicago Press, 1954), vol. 2.
10. E. Bullard, A. E. Maxwell, R. Revelle, in *Advances in Geophysics,* H. E. Lansberg, Ed. (Academic Press, New York, 1956), vol. 3.
11. T. S. Lovering, *Trans. Am. Geophys. Union* 39 (Oct. 1958).
12. H. H. Hess, *J. Marine Research (Sears Foundation)* 14 (Dec. 1955).
13. F. A. Vening-Meinesz, J. H. F. Umbgrove, P. H. Kuenen, *Gravity Expeditions at Sea 1923–32* (Waltman, Delft, the Netherlands, 1934), vol. 2.
14. H. S. Ladd, E. Ingerson, R. C. Townsend, M. Russel, H. K. Stephenson, "Drilling on Eniwetok Atoll, Marshall Islands," *Bull. Am. Assoc. Petrol. Geologists* 37 (Oct. 1953).

Karl Spencer Lashley, Experimental Psychologist

Karl Spencer Lashley was born in Davis, West Virginia, on 7 June 1890 and died suddenly in Poitiers, France, on 7 August 1958. He was one of the world's greatest experimental students of brain function in relation to mammalian behavior. He established a quantitative association between neocortical mass and habit formation and made other basic contributions to physiological psychology and neurology.

Lashley was a graduate of the University of West Virginia and held the degree of master of science in bacteriology from the University of Pittsburgh and the degree of doctor of philosophy in genetics from the Johns Hopkins University. His first paper, published in 1912, was on visual discrimination of size and form in the albino rat. He also wrote two papers, with H. S. Jennings, on biparental inheritance in paramecia. In the next few years Lashley published a series of papers jointly with the late J. B. Watson, the behavioristic psychologist, dealing with the adaptive life of a number of animal forms. One of these was a study of homing in birds. Another was an often quoted paper on the nest-