RESEARCH PROGRAMS

Fifth force finished?

Recent experiments involving the decay of K_2^0 mesons indicate that a proposed fifth fundamental force does not appear to exist. The new force had been suggested as an explanation for the discovery by J. H. Christenson and collaborators,[1] that K_2^0 mesons seemed to decay into π^+ and π^-. This decay is forbidden by *CP* invariance, which requires that in particle interactions, the eigenvalue of the product of the charge conjugation operator, *C*, and the parity operator, P, remain the same. If *CP* invariance is violated, this implies that time is not reversible in the interaction, since the product of *C*, *P*, and *T* (the time reversal operator) is believed to be conserved.

The denial of time reversal invariance is, however, very hard to take. Shortly after the forbidden decay was found, two groups of theorists independently proposed an alternate way out of the dilemma. J. S. Bell and J. K. Perring[2] suggested: "Before a more mundane explanation is found, it is amusing to speculate that it might be a local effect due to the dissymmetry of the environment, namely the local preponderance of matter over antimatter." The authors went on to propose the existence of a very weak (only 10^{-10} as strong as gravity), long-range force which acted on hypercharge, just as the electromagnetic force acts on charge. This "fifth force" (fifth in addition to the strong, weak, electromagnetic, and gravitational forces) would act differently on matter and antimatter. The theory also proposed a neat way of testing the existence of the "fifth force", since it predicted that the number of two-pion decays would be proportional to the square of the energy of the decaying kaons.

Neutral K mesons exist in two states: K^0 with positive strangeness and $\bar{K}^0$ with negative strangeness. But when the neutral kaon decays, this process is described in terms of the K_1^0 and the K_2^0, which are each fifty-fifty mixtures of the K^0 and the $\bar{K}^0$. It happens that K_1^0 has a much shorter lifetime than the K_2^0. The path of the neutral kaon beam in the Christenson experiment was long enough for all the K_1^0 particles to decay before reaching the detector. Hence, if any π^+ and π^- pairs were found, they were presumably caused by K_2^0 decays.

If there were a fifth force, acting differently on matter and antimatter, there would be different amounts of K^0 and $\bar{K}^0$ in the kaon beam. Thus the mixture of K^0 and $\bar{K}^0$ which describes the K_2^0 would be changed, and so would the mixture for the K_1^0. This would amount to the reappearance of some K_1^0 particles which could then be detected as two-pion decays, thus conserving *CP* invariance.

Last month two separate groups reported preliminary results that showed no evidence that the two-pion decay ratio increased as the square of the kaon energy, but did confirm the results found by the Christenson group. A team at the CERN synchrotron[3] found that the ratio of two-pion decays to all other K_2^0 decays was $(3.5 \pm 1.4) \times 10^{-3}$ at a kaon momentum of about 10 BeV/*c*. Another group, at the British Nimrod accelerator,[4] found the ratio to be $(2.08 \pm 0.35) \times 10^{-3}$ averaged over the K_2^0 momentum spectrum, which extended from 1.5 to 5.0 BeV/*c*. The Christenson group had found a ratio of $(2.0 \pm 0.4) \times 10^{-3}$ at an effective momentum of 1.1 BeV/*c*.

References

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Program for geophysics

A three-year study of the future course of research in solid-earth geophysics in the United States, carried out by some of America's leading geophysicists, has recently culminated in a report on the subject, published by the National Academy of Sciences. Entitled *Solid-Earth Geophysics: Survey and Outlook*,* it represents a joint effort of the Academy's Division of Earth Sciences and Geophysics Research Board. The study upon which it is based was made possible by the continuing support provided by the National Science Foundation to the Geophysics Research Board.

Scientists, the report observes, have barely scratched the surface of the earth. Until recently, even its external features (in particular, the Arctic, the Antarctic, and the two-thirds of the earth's surface which are water) have remained largely unexplored. Very few of the earth's properties can be isolated and measured separately. Some properties, such as the gravity field, transmission of seismic waves, densities, and elastic properties of rocks and minerals, can be measured, but the geophysicist still must relate this data to the structure, composition, and processes inside the earth, below the region he can investigate directly. The known facts about the interior are few, and they often have been obtained by involved reasoning and deduction. The report notes that more is known about the surface of the moon than about the earth's mantle which lies only twenty miles or so beneath our feet.

Briefly, the gross details of the earth's size and shape are understood; we know its mass as accurately as we know the gravitational constant (to a few hundredths of one percent); the positions of the earth's center of mass and of the continents are known to the same accuracy; from the precession of the equinoxes it is known that the earth's mass is more

*The report, priced at $4 per copy, is available from the Printing and Publishing Office of the National Academy of Sciences, 2101 Constitution Avenue, N.W. Washington, D.C. 20418.

concentrated toward the center than could be expected in a homogeneous body of the same dimensions and mean density. Seismic studies have revealed a major discontinuity in the earth at a depth near 2900 km. Beneath this is the core, the outer part of which appears to be "liquid", since seismic shear waves are not transmitted through it. Above the core is the mantle, which includes $\frac{7}{8}$ of the total earth volume, and above it is a thin crust whose physical properties are quite different from those of the mantle. In addition, approximate values of pressure, seismic-wave velocities, and densities at various depths are known. The report indicates that these statements describe the main, well-established facts, and that all other information about the earth's interior, having been obtained by much piecing together of various evidence, may be considered suspect. One outstanding gap in geophysical knowledge is the almost completely unknown distribution of temperatures below a depth of a few hundred kilometers. It is not even certain whether the interior of the earth is heating up or cooling down.

In view of the success of the International Geophysical Year, the organization of a comparable international program in solid-earth geophysics was proposed and endorsed in 1960 at a meeting of the International Union of Geodesy and Geophysics in Helsinki. More than forty nations, including the United States, have agreed to take part in the proposed "Upper Mantle Project". The National Academy of Sciences was responsible for recommending a United States program to be carried out under the international project. The task of drafting a proposal for the national program was assigned to the Panel on Solid-Earth Problems, which was organized in 1961 under the Academy's Geophysics Research Board and the Division of Earth Sciences. The panel submitted its recommendations for the proposed program in November 1961, based on an estimate of the worthwhile activities that could be undertaken promptly in accordance with the international recommendations. At that time, the panel was also called upon to conduct a study of the problems and challenges in research pertaining to the physics and chemistry of the solid earth and to provide estimates upon which a ten-year national program in solid-earth geophysical research might be based. The present report is a result of that study.

According to the panel, the problems outlined in planning for the Upper Mantle Project are too complex to be answered during the period reserved for the international effort and instead "seem destined to occupy geophysicists and geologists for many years". Terming them among the most pressing of the coming decade, the panel paraphrased these problems in the following manner:

> To understand the causes of tectonic and magmatic processes it is necessary to determine the variation of the physical and chemical properties of the upper mantle and lower crust, both radially and laterally, to determine present and past movements of these materials, and to find the sources of their energy. How do the materials of the upper mantle and crust differ between continents and oceans, between the stable areas of the ancient shields and the modern chains of folded mountains, between the plateaus and the plains, between the rift zones and the batholithic masses of granite, between island arcs and abyssal plains, between ocean deep and ocean rise? What is the mechanism at the earthquake focus? Does the mechanism differ in deep-focus quakes from that in shallow? What is the nature of the boundary between crust and mantle? How do electric and magnetic properties and the low-velocity zone in the upper mantle vary with area and with depth? Are there intermediate crustal layers separated by sharp boundaries? How can we locate zones in the crust and mantle that are near the melting point? How can we determine the mechanisms of tectonic and magmatic processes and trace their evolution through geological time?

The relationship between the special program for the Upper Mantle Project and the proposed ten-year United States program is reflected in the recommendations contained in the Academy's report. In addition, the panel urged that an interdisciplinary committee devoted to the physics and chemistry of the solid earth be established by the International Council of Scientific Unions to stimulate continuing international programs parallel to the proposed national effort.

In its specific recommendations, the report emphasized the following:

1. Laboratory studies of various geological materials should be stressed.
2. Holes for heat-flow studies should be drilled throughout the United States with a spacing of approximately 200 kilometers. Perhaps as many as one thousand holes, ranging in depth from 300 to 1500 meters, should be drilled during the ten-year period.
3. Deep drilling (3 to 8 km) should be carried out in selected areas, and a study should be undertaken to determine the feasibility of drilling to depths of 12 to 15 km.
4. A number of new facilities should be established, including a permanent facility for recording gravity observations and preparing gravity maps of the US, a geodetic data center for compiling and distributing data on a worldwide basis, a laboratory for shockwave experimentation with emphasis on geophysical problems, and a laboratory to study basic principles of concentration of elements. University geophysical facilities should be expanded at a minimum rate of $3 million per year, and the equipment of seismic observatories should be modernized.
5. Since the number of graduate students in solid-earth geophysics is expected to triple in the next decade, at least 200 new fellowships and 75 new faculty positions should be established.
6. Topographical, geological, gravity, and magnetic mapping should be stressed to achieve total coverage of the entire country in the shortest possible time.
7. Intensive regional studies of major geological structures should be carried out. One such study would be the Transcontinental Geophysical Survey, covering a band 250 miles wide from the Atlantic to the Pacific and extending at both ends to the oceanic basins.
8. Techniques for gravity and geodetic measurements should be improved and the instruments and methods of seismology should be developed extensively.
9. Arrangements should be made to establish stand-by capabilities for prompt observation of major natural events such as last year's Alaskan earthquake.
10. Computer time should be made available for theoretical studies and data handling, and research should be encouraged to develop and improve computing and data-handling techniques for geophysical research.

Additional recommendations called for industrial cooperation in the national program and for cooperative international investigations to be conducted abroad. In general, the program outlined in the report would mean an increase in the annual level of support for solid-earth geophysics from the present $25 million to $65 million by the end of the decade.

Site for Project Mohole

The location of the hole to be drilled through the earth's crust to the mantle as part of Project Mohole will probably be in the mid-Pacific about one hundred miles north northeast of Maui in the Hawaiian Islands. This drilling is one of the major objectives of the project, whose mission is to obtain and study samples of the earth's crust down to and including the unexplored mantle. The choice of site was recently announced jointly by the National Science Foundation, the National Academy of Sciences–National Research Council, and Brown & Root, Inc., the prime contractor for Mohole. The announcement stressed that this is an initial decision subject to change if further information indicates another site would be preferable.

The search for the proper site began six years ago. The most important consideration was the depth to the mantle, because drilling difficulty increases rapidly with depth. Leland J. Haworth, NSF Director, remarked that it is not expected that drilling deeper than 35 000 feet will be possible. The water depth at the Hawaiian site is 14 000 feet, and at this spot it is estimated that the distance from sea level to the mantle is between 28 000 and 31 000 feet.

This month a shipyard will probably be selected to build Mohole's drilling platform, a column-stabilized, twin-lower-hull, semisubmersible structure. The upper hull, 279 feet long, 234 feet wide, and 23 feet deep, will be supported by six columns. The drilling derrick will extend 240 feet above the upper deck and the height from baseline to upper deck will be 135 feet.

A second major objective is an experimental drilling program which is to be conducted at six other locations in the Pacific, beginning in 1967. Initial drilling to the mantle