chairman of the department. . . . **Clyde M. Senger**, professor of biology, Western Washington State College, to chairman, biology department at the college. . . . **Karl R. Johansson**, deputy director for scientific affairs, Wistar Institute, to chairman, biological sciences department, North Texas State University. . . . **G. King Walters**, acting dean of science and engineering, Rice University, to chairman, physics department at the university. . . . **Albert J. Stunkard**, head, psychiatry department, University of Pennsylvania School of Medicine, to chairman, psychiatry department, Stanford University School of Medicine. . . . At the University of Florida: **Harry H. Sisler**, executive vice president, University of Florida, to dean, Graduate School; **John W. Hardy**, curator, Moore Laboratory of Zoology, Occidental College, to chairman, natural sciences department; and **William R. Maples**, associate professor of anthropology, University of Florida, to chairman, social sciences department. . . . **Erich H. Windhager**, professor of physiology, Cornell University Medical College, to chairman, physiology department at the college. . . . At the University of Miami: **John E. Davies**, associate professor of medicine, School of Medicine, to chairman, epidemiology and public health department; and **Francis Williams**, research biologist, Scripps Institution of Oceanography, to chairman of fisheries and applied estuarine ecology. . . . **Joel Greenspoon**, professor of psychology, Temple Buell College, to chairman, psychology department, College of Arts and Education, University of Texas of the Permian Basin. . . .At Howard University School of Medicine: **William L. West**, professor of pharmacology, to chairman, pharmacology department; and **Melvin B. Jenkins**, professor of pediatrics, College of Medicine, University of Nebraska, to chairman, pediatrics and child health department. . . . **Tomas A. Arciniega**, professor of educational administration, University of Texas, El Paso, to dean, School of Education, California State University, San Diego. . . . **James M. Sawrey**, chairman, psychology department, California State University, San Jose, to dean, School of Social Sciences at the university.

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RESEARCH NEWS

Deep Sea Drilling: Research Lags Exploration

Week after week, month after month, the *Glomar Challenger* plies the world's oceans, drilling and coring sea-floor sediments. Every 2 months, it docks to take on a fresh scientific staff that to date has included some 330 investigators from 23 countries. Periodically the ship's load of samples is transferred to repositories at Scripps Institution of Oceanography in California and Lamont-Doherty Geological Observatory in New York, which together contain more than 25,000 meters of recovered cores. Now on the thirty-first leg of its continuing voyage of discovery, the *Glomar Challenger* has traveled more than 160,000 nautical miles and has drilled 450 holes into the ocean floor at 300 sites located in every major ocean basin except the Arctic. Technical innovations demonstrated with the ship range from extremely accurate positioning of the vessel and an ability to reenter a drill hole to successful operation of the longest drill string ever suspended from a floating platform.

Like its namesake, H.M.S. *Challenger*—whose pioneering 3½ year voyage a century ago marked the beginning of oceanographic research—the *Glomar Challenger* began its expedition in a time of scientific ferment. The *Challenger* set forth not long after the appearance of Darwin's *The Origin of Species* and opened investigation of the great ocean basins. The *Glomar Challenger* began its voyage for the National Science Foundation's Deep Sea Drilling Project (DSDP) during the conceptual revolution and debate over what is now called plate tectonics and hence had as a principal goal the determination of marine geologic history. Of particular interest were what at the time could only be called radical geophysical hypotheses—continental drift, sea-floor spreading, the notion of continually shifting crustal plates.

In 5 years of plumbing the sedimentary record contained in the sand, silt, volcanic ash, and fossil debris that overlie the oceanic crust, the drilling project has unequivocally established the geological youthfulness of that crust in comparison to most continental rocks and has helped confirm that sea-floor spreading and widespread crustal motions have occurred. These results, which became apparent early in the project, gained for the DSDP a reputation as one of the more successful examples of big science. More recently the results announced at the end of each leg of drilling, and examined in greater detail in an initial report by the scientific staff of each cruise, have been relatively modest. Cumulatively, however, they add up to a much broader, if still incomplete, picture of the history of the ocean basins than was heretofore available.

The pattern of movements of the crustal plates, for example, appears to be more complex than anticipated. In addition to east-west motion (away from the mid-ocean ridges where new crust is formed), the Pacific plate is moving northward, as is the floor of the eastern portion of the Indian Ocean near Australia. Vertical motions, both subsidence and uplift, also appear to have occurred. A major submarine ridge in the Indian Ocean, more than 2000 kilometers long and now more than a kilometer below sea level, has deposits of coal and shallow water shells that indicate it was once a chain of islands with swamps and lagoons. More generally, most oceanic crust appears to subside as it grows older and moves away from spreading centers toward deep ocean trenches.

The drilling has turned up evidence of petroleum and mineral deposits that may eventually be of commercial importance. Petroleum and natural gas were found for the first time in deep sea conditions in salt domes under the Gulf of Mexico. Trace amounts of natural gas have been detected in cores from many parts of the world. Sedi-

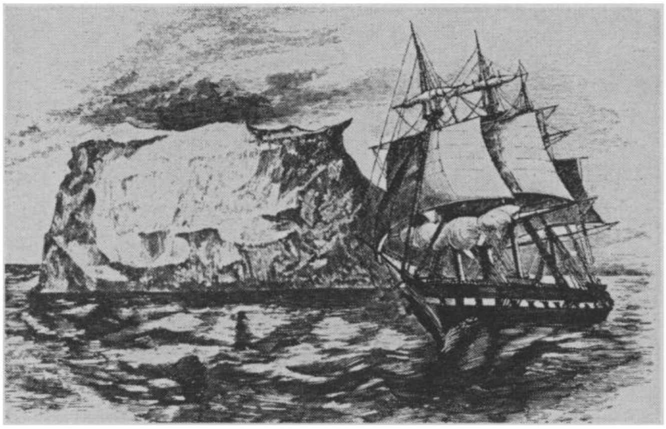
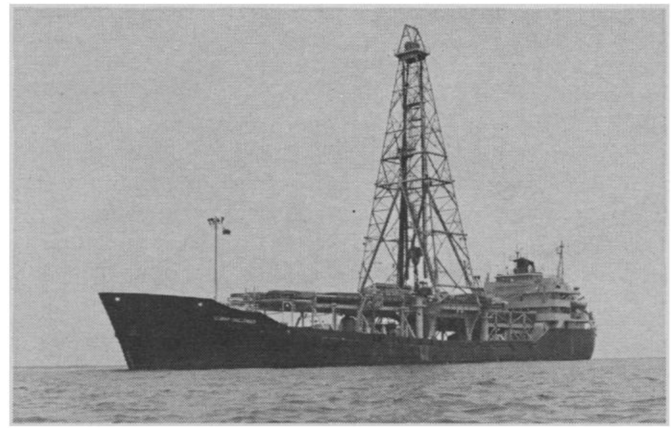

Fig. 1 (left). H.M.S. *Challenger* in Antarctic waters, 1874. The ship, a converted gunboat, was 200 feet in length and carried a scientific and naval crew of 29 persons. [Source: Scripps Institution of Oceanography] Fig. 2 (right). *Glomar Challenger* operated by Global Marine, Inc. for the Deep Sea Drilling Project. Drilling is done through a well located amidship directly under the derrick. The ship is nearly 400 feet in length and carries a total crew of 68 persons. [Source: Scripps Institution of Oceanography]

ments rich in metals—iron and manganese, with smaller amounts of copper, lead, and zinc—have also been recovered from many areas. The deposits seem to form in the lowest layer of sediments just above the igneous crust. Although these discoveries have not discernibly led to commerical exploration activity, they have contributed to a sense of urgency regarding the need for international regulation of mineral rights and other natural resources in and under the sea.

A third and more difficult to characterize class of results from the DSDP concerns physical and chemical changes bearing on climatic history and paleoceanography. The Mediterranean Sea appears to have been cut off from the Atlantic Ocean between about 5 and 10 million years ago, during which time the water evaporated, depositing thick layers of salt and leaving the basin dry, empty, and devoid of marine life. At the other extreme of climate, Antarctica appears to have been glaciated for at least the past 20 million years, far longer than previous estimates of the extent of the most recent ice age. About 5 million years ago, the drilling evidence suggests, the ice cap suddenly receded to its present size, a change that would have noticeably raised mean sea level.

The bottom water in the world's oceans contains oxygen as a result of circulation patterns that bring cold surface water from the vicinity of either pole to the depths. The sedimentary record suggests that similar circulation patterns existed in the past, except in the North Atlantic where prior to 80 million years ago the bottom water was not oxygenated. Other changes in circulation patterns, such as the establishment of the circumpolar current after Australia separated and moved away from Antarctica, are thought to be a cause of major gaps in the sedimentary sequences recovered by the drilling program. The strong current, according to the hypothesis, may have eroded sediments or prevented their deposition over wide areas.

Among the highlights of the *Glomar Challenger*'s most recent cruises are the results of two legs of drilling in the hazardous waters surrounding Antarctica. In addition to documenting the extent and duration of the south polar ice cap, sedimentary evidence in the recovered cores confirmed how first New Zealand, between 60 and 80 million years ago, and shortly thereafter Australia broke away from Antarctica and moved northward. Five legs of drilling in the Indian Ocean produced evidence of pieces of oceanic crust that had been uplifted and tilted, and then later had subsided. Other findings include an estimate of the time (60 million years ago) when India stopped moving northward and some samplings of the igneous rocks that make up the oceanic crust. The island of Madagascar, thought by some geophysicists to have separated recently from eastern Africa, was found instead to have been an independent minicontinent for at least the last 100 million years. Drilling in the Arabian Sea turned up rocks that were fractured and folded presumably at the time the Himalayas were being formed 1500 km to the north; the deformation was the more surprising because it occurred in the middle of, rather than at the edge of, a crustal plate.

The drilling cores contain an immense store of information on marine geology that should eventually yield a more coherent picture of the history of the ocean basins and the processes that formed them. Work on diagenesis (mineralogical processes in sediments), on changes of oceanic circulation with time, and on the role of bottom water in controlling oceanic geochemistry is only beginning. The research is inherently interdisciplinary—the mineralogist must depend on the biostratigraphy of the paleontologist and on the tectonic reconstructions of the geophysicist—and hence is difficult for the individual investigator who must deal with all aspects of the raw cores himself. Synthesis has not progressed far beyond the statement that the oceanic crust is of recent geological origin—still probably the most significant finding of the DSDP.

Indeed, except for preliminary dating and characterization by the scientific staff of the *Glomar Challenger,* the miles of core piling up in the repositories have hardly been looked at. In part, this neglect of what is seemingly an unparalleled scientific resource is due to delays in making samples available to the scientific community. The policy under which DSDP cores were distributed, in sharp contrast to that followed by the National Aeronautics and Space Administration in distributing lunar samples from Apollo, required that no samples be given out until after publication of the scientific crew's initial report—a process that often lagged completion of the cruise by 2 years or more. Thus while protecting the crew against being scooped on their findings, the policy left most marine geologists dependent on word-of-mouth reports as to detailed composition of the cores. In an effort to alleviate this situation, the DSDP last year began distributing cores 1 year after the cruise and this month begins making descriptions of the cores (in preprint form) available after 6 months.

Nonetheless, NSF has not been overwhelmed by requests to study the cores and problems in obtaining information about or gaining access to the cores do not seem to be the only reason. While recognizing the potential wealth of information to be gained from the cores, few scientists in the marine geology and oceanographic communities have done much about it. The press of ongoing research, the reluctance of specialists to venture into new fields, and the exhaustion of many of those participating in the cruises and the writing of the initial reports (which commonly run to 1000 pages or more each and amount to a not inconsiderable resource) are all offered as explanations for the slow response to the DSDP cores. It also appears that there has been a lack of planning for how to use the cores and how to facilitate follow-up studies.

According to Melvin Peterson of Scripps, project manager and co-principal investigator of DSDP, requests for core samples are now increasing exponentially and the project is beginning to construct a computerized data retrieval system that will aid those seeking to study the cores and will produce maps, depth profiles, and similar guides to the data by geological region. Nonetheless some marine scientists are concerned that the drilling project is piling up cores at a rate that far outstrips their scientific utilization and that consequently there is not enough feedback into the planning of the program.

To Tj. H. van Andel of Oregon State University, who was active in planning for the DSDP and is currently one of the principal users of core samples in his research, the practice of preparing only the crew's initial reports on the cores is less and less satisfactory, and the many discrepancies in these reports make them useful only to an expert. He believes what is needed is a pause in the drilling and diversion of some of the money to cleaning up the existing data and making it accessible for a wider scientific audience. J. Hays of Lamont-Doherty points out that the drilling techniques used in the program needlessly mix many of the softer sediments, so that undisturbed sequences of sediments are not being obtained. He believes that if more scientists were studying the cores, there would be considerable pressure for improvements in the coring techniques which could easily yield much greater precision in an historical record that will be used by generations of scientists.

The *Glomar Challenger* is soon to be fitted with a system designed to compensate for the ship's heave, a modification that may improve the quality of the cores recovered and allow deeper penetration into sediments and the underlying crustal rocks. Plans for forthcoming legs include additional drilling near Antarctica and a preliminary attempt to penetrate deep into the oceanic crust off South America and near the mid-ocean ridge in the North Atlantic.

The drilling program is expensive—it costs about $10 million a year—a sum that does not include funds for research on the cores other than the crew's initial reports. Proposals for research involving the DSDP cores must compete at NSF with existing interests in marine geology and geochemistry, and, according to some observers, are comparatively more difficult to obtain funding for. Officials at NSF dispute this, claiming that a higher percentage of proposals for work with the cores are funded than the average for the relevant disciplines. In any case, far less is spent on research with the cores than on obtaining them, although this discrepancy is perhaps not surprising in view of the cost of sending a ship out. More serious are the questions of whether the cores are being properly utilized and how much longer the drilling program, and its expense, should continue.

Forge Ahead or Fund More Research?

The DSDP is the largest program going in the earth sciences, and, understandably, most scientists directly concerned are of the opinion that drilling should continue. They believe that a project of this magnitude, once stopped, would be very difficult to restart—an argument that is not without credence in today's climate of budgetary stringency. Hence there is considerable incentive to forge ahead despite the lag in research. The DSDP has twice been extended, a convincing tribute to its initial successes, and drilling is now scheduled to continue through August 1975.

Already, however, plans are afoot for the period after 1975. One idea is that the drilling would continue under an expanded charter, with multinational participation in its scientific direction and funding, as the International Program of Ocean Drilling (IPOD). The Institute of Oceanology of the U.S.S.R. has already become a member of the group of institutions that provide scientific advice to the DSDP, and the Soviet government will contribute $1 million a year toward the cost of the drilling beginning this fiscal year. West Germany and other nations have also expressed an interest in joining and contributing.

As envisioned in the IPOD proposal now being studied by NSF, emphasis of the drilling would shift from general reconnaissance of the sea-floor sediments to investigation of the oceanic crust underlying the sediments and later to study of continental margins with an eye toward evaluating mineral and petroleum resources. These goals would involve drilling fewer but deeper holes to recover samples of the hard rock forming the crust and to penetrate the 3 to 5 km of sedimentary material that overlies the crust in offshore regions. Sedimentary drilling would be continued but would be focused on specific geological problems arising from study of the cores already obtained.

The difficulty confronting the IPOD proposal and the remaining portion of the DSDP is that the geophysical questions for which the preliminary results of the drilling project were especially appropriate have for the most part been answered, and significant new questions based on more detailed study of the cores have been slow to emerge. There seems to have been a reluctance on the part of all involved to face up to the need for closer management and coordination of the research that big science projects demand. As one member of the DSDP planning committee put it, "We need a real tightening up of the project to increase its scientific return." The cores represent a unique scientific resource, comparable to the lunar samples—a fact recognized by the growing number of countries willing to help pay for the drilling program. What is needed are arrangements for its continuation that will more fully realize the enormous potential of the core materials.

—ALLEN L. HAMMOND