Appendix B

Background on Deep Ocean Drilling for Scientific Purposes

BACKGROUND ON DEEP OCEAN DRILLING FOR SCIENTIFIC PURPOSES

THE MOHOLE EXPERIMENTAL DRILLING PROGRAM .PHASE I

Marine geologists and oceanographers have long desired to study samples from deep in the sediments and rocks beneath the ocean floor in order to extend man's knowledge of the earth and its history. In 1957 a distinguished group of these scientists joined together in an informal association known as the American Miscellaneous Society (AMSOC). This group concluded that the greatest advance in the earth sciences could be made by drilling through the crust of the earth to the mantle. This boundary was known as the Mohorovici Discontinuity (MOHO) - hence the name *MOHOLE*. By continuous coring and measurement of the characteristics of the sediments and rocks, many of the theories developed by indirect methods could be tested against the direct evidence obtained from the hole.

It soon became evident that the goal could be reached most expeditiously by drilling in the deep ocean basins where the crust was known to be thinnest (18000 to 12000 feet) and the least drill penetration would be required. However, in these locations the water depths ranged from 12000 to 18000 feet, thus requiring a drill string length equal to or greater than 30000 feet to reach the MOHO. This drill string requirement exceeded by 5000 feet the deepest penetration achieved on land up to that time and the then current offshore drilling operations were limited to maximum water depths of about 600 feet.

Undaunted by the formidable challenge posed by major advances required in the state-of-the-art of drilling at sea, the AMSOC group became a formal committee of the National Academy of Sciences (NAS) and obtained funds from the National Science Foundation (NSF) to investigate potential approaches to the problem. In November 1959 a study group, comprising oil industry and marine industry specialists, studied the possibility of conducting an experimental drilling program in deep water. This would involve drilling into the soft sediments of the deep ocean floor from a dynamically positioned vessel to establish whether it was feasible to extend such operations to greater penetration depths and to maintain position of a floating drilling platform for long periods under difficult environmental conditions. The conclusion, reported in March 1960, was that the experimental program could be carried out , and would yield valuable information on which to build future plans; the initial study group estimate for this Phase I Drilling Program was $522,550.

NSF agreed to fund the program and engineering work and scientific planning began in earnest. As a result, the Global Marine Exploration Company drilling vessel *CUSS I* was drydocked for conversion on 14 February 1961 in San Diego, and by 7 March the vessel was underway for test drilling in 3100 feet of water off La Jolla, California. Within the following week, five holes were drilled, the deepest being 1035 feet which was drilled through a tapered guide casing above the bottom and with casing extending about 100 feet into the bottom.

After a week of refit and upgrading of some equipment in the San Diego shipyard, the *CUSS I* proceeded to the deep water drilling site between Guadalupe Island and Baja, California. On 28 March the bit touched down and drilled into the deep sea floor for the first time; water depth was 11672 feet. Five holes were drilled, the greatest penetration being 600 feet below the sea floor of which the lower 50 feet extended below the sediments and into basalt. Collectively, the cores obtained represented almost 100% sampling of the sediments and rock down to this penetration depth 12272 feet below the ocean surface.

The Mohole Experimental Drilling Program was considered entirely successful, far exceeding the expectations of the AMSOC Committee and its sponsors. In addition to the scientific value of the cores obtained and the measurements made, the following engineering and operational features were proven:

- Dynamic positioning, or stationkeeping with controlled propulsory instead of anchors, was an entirely acceptable means of keeping " a drilling vessel on station for extended periods.
- As long as a ship is headed into the principal swell, it is an acceptably stable drilling platform.
- Constant pressure of the drill bit *on* the bottom can be maintained with the proper combination of drill collars and bumper subs.

- Combined use of diamond bits and wire-line coring yields satisfactory core samples from both bottom sediments and rocks.
- Casing of the upper 200 feet of a hole is possible and permits drilling to the above penetration depths without cuttings falling back into the hole.
- Standard logging techniques can be used to obtain geophysical measurements in the strata of the hole walls.
- Oceanic currents were less troublesome than anticipated.
- Cuss I was a suitable vessel for the first experiments but lacks many of the required characteristics of the drilling vessel needed to drill the final MOHOLE.

In addition to these tangible achievements, the Phase I design, construction, and operation program was the first time that the oil industry, offshore operators, the marine industry, and earth scientists had an opportunity to work closely together in the pursuit of a common goal. Each group learned to appreciate the problems and aspirations of the others and a unique understanding and camaraderie developed that has formed the basis for many of the cooperative efforts that have been undertaken in the ensueing years.

The total cost of this program was estimated to be $1,788,000. Of this, $1,501,500 was funded by NSF. Additional government contributions were $35,000 from the U. S. Army, $1,500 from ONR; $250,000 came from industry and university or research organizations. This does not account for several items of equipment that were transferred, without cost, to other projects. For example, the four steering propellers ($130,000) used for dynamic positioning were first given to the Office of Naval Research for use in cable laying in the ARTEMIS program and a number of the dynamic positioning control components were also used in their control systems aboard the YFNB-12. These units and the controls were later transferred to Woods Hole Oceanographic Institution and three of these constitute the propulsion system of *LULU*, the tender for the submersible *ALVIN*. Thus, not only the scientific and engineering fall out from the Mohole Experimental Drilling Program remains as a highly regarded heritage, but much of the hardware is still performing useful functions. Although a benefit/cost analysis was not performed, the ratio certainly far exceeds unity for this program.

THE MOHOLE DRILLING PROGRAM - PHASE II

Based upon the success of Phase I, the National Science Foundation moved rapidly into the initiation of Phase II of the Mohole Drilling Program - the development of a drilling system that could reach the MOHO. Background material was prepared and sent out and, on 27 July 1961, a briefing was given to prospective contractors for the design, construction, and operation of a drilling system capable of reaching the MOHO. Seven months later, in February 1962, NSF announced that the prime contractor was to be Brown & Root of Houston, Texas.

The contractor selection process and the initial work performed by Brown & Root gave rise to a considerable amount of speculation as to the political influence that might have been exerted and the ability of NSF to provide adequate management control over a project of this magnitude. Initial expenditures far exceeded what might be anticipated for the progress made in the design and construction of a deep ocean drilling system with the capability of reaching the MOHO. Furthermore, the scientific community began to express considerable concern over the amount of NSF expenditures for hardware in proportion to the funds made available for science. The ultimate result of the rumors of inordinate political influence, inefficient utilization of funds, and financial neglect of scientific programs was the termination of the project by Congress through the simple expedient of shutting off NSF funds budgeted for the program. This occurred in September 1966.

However, despite the slow start of the prime contractor on the Mohole program, there was a considerable amount of progress made in the last two years that resulted in significant advances-in the engineering aspects of deep water drilling technology. These include:

- o Development of both short baseline and long baseline deep water sonar location systems for application in ship dynamic positioning.
- o Design of retractable, ducted steering propellers for dynamic positioning thrusters.
- o Concept, design, and model testing for propulsion and seakeeping ability of the first semi-submersible drilling platform.

- Concept and design of a casing, reentry cone, and riser system for deep water drilling.
- Development of advanced types of drill bits and coring equipment for continuous coring of holes in the ocean floor.
- Improvement in down hole logging techniques and development of logging equipment.

One has only to look at the number of dynamically positioned, semi-submersible drilling platforms using ducted steering propellers to see that this innovation and technology transfer has been of significant benefit to the offshore oil industry.

Other Mohole developments have proven of great value throughout the world in the extraction of petroleum and associated resources from beneath the floor of the ocean. Thus, although there may have been some waste of funds, and their diversion from other scientific pursuits, the net outcome of the Mohole Program has been beneficial to the nation and to the world.

THE DEEP SEA DRILLING PROJECT (DSDP)

The success of Phase I of Project Mohole in early 1961 demonstrated the feasibility of extending the drilling techniques developed by the oil industry both to very great water depths and to great distances beneath the ocean floor. This success stimulated widespread discussion of possible projects directed at sedimentary drilling as distinguished from the very deep drilling objectives of Project Mohole itself. During the ensuing two or three years several formal and informal proposals were made to the National Science Foundation seeking financial support on behalf of individual institutions or groups of institutions to support sedimentary drilling projects, and for a considerable interval of time there were various serious discussions of the possibility of doing such drilling as an intermediate phase of Project. Mohole.

It ultimately became clear that eventually two quite different types of vessels would be required for deep rock and for sedimentary drilling - a large stable platform to permit drilling in one place for a long period of time to reach the deep mantle rock and a more modest ship that need stay on one station only for sufficient time to penetrate and sample the ocean sediments. Realizing this, the National Science Foundation proposed, in Congressional testimony given in the fall of 1963, that there be instituted an “Ocean Sediment Coring Program” distinct from, but complementary to, the Mohole Project.

As a guide for the planning of such a program, the Foundation staff had many discussions with knowledgeable scientists in the fields of oceanography, geophysics and geology and surveyed the means by which their cooperation could be obtained in carrying out the program. In the spring of 1964, initiative was taken by four of the major oceanographic institutions that had strong interests in these fields, and in May 1964 they formed the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), a consortium that has provided the focal point for setting up scientific advisory panels with broad representation and for otherwise providing advisory planning and guidance to the Project. This group, Lamont-Doherty Geological Observatory; the Institute of Marine Sciences, University of Miami; the Scripps Institution of Oceanography, Universtiy of California at San Diego; and the Woods Hole Oceanographic Institution, expressed an interest in undertaking scientific planning and guidance of the sedimentary drilling program. It was the purpose of this group to foster programs to investigate the sediments and rocks beneath the deep oceans by drilling and coring. The membership of this original group was later enlarged in 1968 when the University of Washington became a member.

Through discussions sponsored by the JOIDES organization, and support from the National Science Foundation the Lamont-Doherty Geological Observatory operated a drilling program with Dr. J. Lamar Worzel as Principal Investigator. This successful drilling effort early in the summer of 1965, on the Blake plateau region off Jacksonville, Flordia, used the drilling vessel, *CALDRILL I*. With this success in hand, planning began for a more extensive deep sea effort. As the discussions and plans progressed indicating the feasibility of such an effort, the Foundation provided for initial funding for the Project in fiscal year 1965 and formally established the ‘National Program” with funds made available in the fiscal year 1966 appropriation. From among their group, the JOIDES consortium-selected Scripps as the best situated and equipped to undertake the management of a continuing drilling effort. Accordingly the Foundation, in the summer of 1966, awarded a contract to the Scripps Institution of Oceanography to conduct the Deep Sea Drilling Project. On 14 November 1967, a subcontract was executed between Scripps

Institution of Oceanography, University of California and Global Marine, Inc., to supply a drilling ship capable of carrying out this drilling program at sea. The ship, constructed especially for the purpose, is capable of drilling in water depths up to 20,000 feet and with a penetration of about 2500 feet into the sea floor. She was launched on 23 March 1968, and christened GLOMAR *CHALLENGER. The* ship was completed and outfitted; drilling operations began in the Gulf of Mexico in mid-August 1968.

The advent of *GLOMAR CHALLENGER,* with its deep-water drilling ability, was exceedingly timely. It came when geophysical investigation of the oceans had matured through 20 to 30 years of vigorous growth to the point where we had some knowledge about much of the formerly unknown oceanic areas of our planet. About one million miles of traverses had been made which told us much about the global pattern of gravity, magnetic and thermal anomalies, and about the composition, thickness and stratification of the sedimentary cover of the deep sea and continental margin. The coverage with such data enabled the site selection panels to pick choice locations for drilling. The knowledge gained from each hole could be extended into the surrounding area. Detailed geophysical surveys were made for most of the selected locations prior to drilling.

The earth sciences had recently matured from an empirical status to one in which substantial theories and hypotheses about major tectonic processes were flourishing. Theories about the origin of magnetic fields and magnetic reversals, about ocean floor spreading, and continental drift, and about the thermal history of our planet, had led to specific predictions that could be tested best by an enlightened program of sampling of deep sea and continental margin sediments and underlying rocks.

The first opportunity to sample the materials of the deep sea floor to significant depths came when *GLOMAR CHALLENGER* drilled her first test hole in the Gulf of Mexico. The many boreholes that have been drilled since that time have made major contributions to better understanding of the nature of the surface features of the earth, the chronology of tectonic and environmental events, the nature of natural disasters, and the geological framework in which economic concentrations of resources are located.

The plate tectonics model was developed from geophysical and geological observations in the oceans and from earthquake seismology. Some of the strongest evidence for its validity has been produced by the Deep Sea Drilling Project. It implies the continuing generation of newly formed crust, primarily at oceanic ridges, followed by lateral transport of the oceanic crust and sediments and ultimate addition to existing continental crust. Along the line where continental and oceanic crust converge the interaction results in the formation of great faults with associated earthquakes, but also, in some little understood manner, the generation of volcanoes and deep seated molten rocks. These are the loci both of natural hazards (volcanic activity and related earthquakes) and of metallic mineral deposits.

A second aspect of the plate tectonics model implies that the present loci of new crust formation developed, in part, beneath a supercontinent some 200 million years ago. With the continued generation of new crust, the rifted continental fragments moved apart toward the present continental configuration, and indeed the relative motion of continents presumably continues today. As the continents move about, circulation patterns in the oceans change, with accompanying changes in weather and climate. The record of these changes is preserved in the sedimentary column on the sea floor. In any case, the rifted margins of the continents were initially thinned and faulted, and ultimately sank beneath the newly formed ocean. All rifted margins show a complicated structural history, leading to similarly complicated patterns of sedimentary deposits. In the initial stages of rifting, isolated seas became the loci of thick salt deposits. In this environment many giant deposits of oil and gas have been found and this remains the most promising domain for the discovery of large additional deposits.

The early phases of the Deep Sea Drilling Project completed a major reconnaissance effort over the ocean areas of the world except the ice-covered Arctic. The Deep Sea Drilling Project has been a relatively expensive earth science effort, but in terms of contributing to a general synthesis of geological knowledge, it has been remarkably economical. Attempts at deeper penetration and additional operations on continental margins are needed to answer important remaining questions and will require continued and increased financial support. This requirement is now being matched in part by the participation of other governments in the drilling effort and by the wish of many scientists throughout the world to increase the scope of the effort.

The first meeting of the representatives of JOIDES with interested foreign parties was held in Washington, D. C., in March 1972, to consider the feasibility of a new international program. Later in that year the JOIDES Planning Committee met to review drafts and prepare a final planning document for an International Program of Ocean Drilling (IPOD).

Until the beginning of IPOD in 1975 the Deep Sea Drilling Project was primarily a global reconnaissance drilling program of ocean sediments. Since then the geographic scope has been limited to those areas in which specific problems associated with ocean crust, margins, and sedimentary regimes can be resolved most definitively. Steaming time of the drilling vessel has been minimized and drilling time maximized by drilling at only relatively few, well-surveyed sites to solve specific problems.

During the IPOD drilling the composition of JOIDES has changed by the addition of several more U. S. oceanographic institutions and by the addition of several non-U. S. institutions. The JOIDES membership is now:

Bundesanstalt fur Geowissenschaften und Rohstoffe
Federal Republic of Germany

University of California at San Diego
Scripps Institution of Oceanography

Centre National pour l'Exploitation des Oceans
Paris

Columbia University
Lament-Doherty Geological Observatory

University of Hawaii
Hawaii Institute of Geophysics

University of Miami
Rosenstiel School of Marine and Atmospheric Science

Natural Environment Research Council
London

Oregon State University
School of Oceanography

University of Rhode Island
Graduate School of Oceanography

Texas A&M University
Department of Oceanography

University of Tokyo
Ocean Research Institute

U.S.S.R. Academy of Sciences

University of Washington
Department of Oceanography

Woods Hole Oceanographic Institution

Drilling with the GLOMAR CHALLENGER has been an outstanding scientific success. The program has been well managed, it has continued and improved upon the high degree of understanding and respect existing between the scientific, offshore operations, and engineering communities, and it has fostered scientific cooperation on an international scale. Yet, although the capabilities of the *CHALLENGER* have been stretched to the maximum, the scientific goals that remain demand a vessel that can work in greater depths of water, can stay more precisely on station for deeper penetrations, and will have a greater carrying capacity. Furthermore, much of the equipment aboard the CHALLENGER is reaching an age where extensive maintenance, rework, or replacement is required. Thus, it appears that the time is rapidly approaching when fulfillment of the expanding scientific goals will call for a newer and more capable drilling vessel.

SCIENTIFIC INITIATIVES IN THE EVOLUTION OF THE OCEAN MARGIN DRILLING PROGRAM

The International Phase of Ocean Drilling (IPOD) was scheduled to be concluded in 1979. The JOIDES organization recognized the need to make a critical examination of the status of scientific ocean drilling and to assess plans for the future in its Executive Committee meeting in August 1976. An *ad-hoc* Subcommittee on The Future of Scientific Ocean Drilling was appointed and directed to hold a conference as soon as possible in order to provide timely advice.

THE FUTURE OF SCIENTIFIC OCEAN DRILLING (FUSOD) REPORT

The FUSOD conference was held in March 1977 and prepared a report of its deliberations, conclusions, and recommendations. This report was revised in April and, in July 1977, it was accepted by the JOIDES Executive Committee. The report detailed a program of future work building upon the knowledge gained in the DSOP and in the IPOD.

One of the more widely cited recommendations of the FUSOD report was the need for extensive pre-drilling planning--geological and geophysical work prior to drilling, and scientific analysis following a drilling program. The committee concluded that any drilling program should proceed only if, "... adequate funding is assured for scientific studies for, i) broad scale problem definition, ii) small scale site examination and preparation, iii) sample analysis and, iv) interpretation and synthesis, as well as logging for each hole."

Future drilling proposals were made by four panels: passive margins, active margins, ocean crust, and paleoenvironment, Cost of the program and equipment use and development were not initially considered by the four panels. All panel recommendations were divided into two phases: 1979-1981 (riserless drilling) and from 1981 on (drilling with a riser). A summary of the panel proposals is given below.

Summary of Proposals by Passive Margin Panel

"The objectives stated by the passive margin panel are:

- o to relate the structural evolution, rifting, and early sedimentation to the nature of ocean-continent boundary and to early history of subsidence
- o to test and improve existing models of passive margin formation and development.

"It is recommended that the major focus of the program be in the North Atlantic where there are excellent examples of two categories of passive margins:

- o mature margin, e.g., the east coast of the U. S.
- o sediment-starved margin on both sides of the North Atlantic."

The initial phase of the drilling program called for shallow penetration drilling in a few carefully selected sites. The second phase involved deep margin drilling with a riser for long periods with extensive advance geophysical survey work.

Summary of *proposal by Active Margin Panel*

"The broad objectives of active margin drilling are to clarify the process of subduction (collision is also important, but it will be the objective in a later stage). These objectives may be subclassified into the following two:

1. Processes in the trench-arc zone
2. Origin and development of back-arc basins.

Current drilling program up to 1979 is designed to attack these objectives with the *GLOMAR CHALLENGER* capabilities by placing transects over selected active margins. The priorities of transects in the current (1977-79) program are as follows:

Priority I — Middle America Trench and South Philippine Sea Transect
Priority II — Kuril-Okhotsk-Japan Transect
Priority III — Northern Philippine Sea Transect
Priority IV — Caribbean, New Hebrides, Tonga and Peru-Chile Transects

However, during the current IPOD program, only Priority I, II, and III transects will be attacked."

The proposed first phase of the active margin panel proposal included intensified geophysical site surveys, downhole instrumentation, “a more detailed network of holes, and an integrated multidisciplinary approach with land geology."

The post 1981 proposal envisioned a program with and without deep drilling capability. Shallow drilling, primarily in the accretionary wedge in subduction zones plus geophysical work was proposed. With a deep drilling capability, a network of holes into the accretionary wedge and back-arc basin drilling was designated in such areas as the Peru-Chile Trench, the Japan Arc systems, and the Marianas Trench.

Summary of Proposa!s by Ocean Crust Panel

"The main objective of oceanic crust drilling is to learn in detail about the geodynamic processes of the evolution of oceanic crust. Three major sets of problems can be identified:

- o geophysical problems, such as the interpretation of heat flow, magnetic anomalies;
- o physiochemical problems such as hydrothermal processes, metrological differentiation, etc.;
- o nature of the deep oceanic crust.”

The 1979-1981 proposed plans included hydrothermal processes, studying crustal structures in the region of transform faults, and examination of the area of Tuamotos. Post 1981 plans were directed at two objectives: to drill into the deep ocean crust and investigate the ocean crust formed in the early stages of spreading.

summary of Proposal by Paleoenvironment Panel

"For a first phase of drilling (1979-81) the South Atlantic has been selected as the most suitable area to develop hypotheses to explain the problems posed by physiochemical changes which occur during the opening and evolution of an ocean. It is proposed to focus on two major aspects of these processes:

1) the transition from stagnant to well-oxygenated conditions
2) the transition from a warm to a cold ocean.

These two major problems can be approached in the South Atlantic in order to understand the main processes involved. In the second phase, post 1981, a more generalized test of the concepts derived from the South Atlantic pilot study should be attempted to elucidate the evolution of a world ocean." Global coverage was cited as crucial to reconstruct paleoceanographic evolution of the world.

General Conclusions and Recommendations

When the FUSOD subcommittee undertook its work the availability of the GLOMAR *EXPLORER* was anticipated in providing a candidate for a drilling vessel with expanded drilling capabilities. Following the individual panel proposals, the FUSOD committee selected overall options for a future ocean drilling program with consideration of budgetary and equipment constraints but excluding *EXPLORER* conversion and riser development costs.

The preferred option included a continuous program of extended *CHALLENGER* use (seven years), and six years of *EXPLORER* work which would fulfill many of the panel proposals. The importance and advantage of a continuous drilling program, from the *CHALLENGER* to the *EXPLORER* was emphasized as well as the importance of performing non-drilling research.

THE AD-HOC ADVISORY GROUP FOR FUTURE SCIENTIFIC OCEAN DRILLING= GILETTI REPORT

The *Ad-Hoc* Group for Future Scientific Drilling (Giletti Group) was established by the National Science Foundation to evaluate the Deep Sea Drilling Project, review the FUSOD/JOIDES report as well as a Scripps proposal for the continuation of deep sea drilling, examine other options for a marine geosciences program which would not involve drilling, evaluate proposals offered by the FUSOD subcommittee, and present scientific priorities for the National Science Foundation directorate.

The Giletti Group, in its report of 2 May 1978, endorsed a scientific drilling program designed to obtain both sedimentary and basement rock samples employing riser technology and blow-out prevention coupled with geological, geophysical, and follow-up research. The Group supported both the scientific studies of the passive margin, active margin, oceanic crust, and paleoenvironment panels, and the general solutions presented by the FUSOD subcommittee.

Conversion of the *GLOMAR EXPLORER* or use of a similar type vessel was recommended. As in the FUSOD report, the Group supported a continuous drilling program until an EXPLORER-type vessel was available. The CHALLENGER could also perform ancillary drilling at certain sites during this time.

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As in the USOD report, the Giletti Group concluded that a drilling program is "not the end objective". There should be extensive site surveys, downhole logging and instrumentation, and other studies to complement the drilling program. Drilling on the passive margins was considered to be of great importance to assist in resource assessment and recommended that "passive margin drilling, at least in the beginning, be off U. S. shores".

THE AD-HOC PANEL TO INVESTIGATE THE GEOLOGICAL AND GEOPHYSICAL RESEARCH NEEDS AND PROBLEMS OF CONTINENTAL MARGINS- BALLY REPORT

This *ad-hoc* panel was established in 1979 by the Ocean Sciences Board of the National Research Council with support from the National Science Foundation, the Office of Naval Research, and the U. S. Geological Survey.

The report of this panel presented recommendations for research in the 1980's which would contribute to a greater understanding for major geological processes of continental margins. Generally, the panel recommended focusing on domestic continental work, greater utilization of existing technology, and finally, a drilling program for "scientific purposes following detailed geological and geophysical surveying".

Three programs were designated as high priority work for the future:

1. A sediment dynamics program to examine sediment transport, entrainment and deposition on continental shelves, slopes, rises, and marginal basins.

2. A program of geophysical and geological traverses, both land and marine, on domestic continental margins.

3. The outfitting of two geophysical research vessels, one for the East Coast and Gulf, and one for the West Coast and the Alaskan margins.

Two programs were designated as second priority:

1. Geological and geophysical traverses of foreign continental margins.

2. Drilling on continental margins, "but only if adequate funding is assured for scientific studies that include: 1) broad-scale problem definition, 2) small scale site examination and preparation, 3) sample analysis and well logging, and 4) interpretation and synthesis".

The report summarized rough cost estimates for each major research program described. The very high costs for drilling were used to emphasize the need for funds directed towards the numerous related research projects.

THE BLUE RIBBON COMMITTEE ON POST-I POD SCIENCE

The Committee on Post -I POD Science was created by the National Science Foundation in July 1979 to evaluate the proposed Ocean Margin Drilling Program, principally as presented in the FUSOD report. The panel was asked to review and critique: 1) the science to be performed, 2) the relation between the proposed science program and 'national needs" -- resource assessment, and 3) the drilling program.

The Committee endorsed the OMD program and recommended the program be given "high priority" consideration in the FY81 budget process at the Foundation. They concluded that the OMD program should be funded through add-on dollars or new money to the NSF budget to avoid competition with other science projects. Other recommendations presented by the committee were:

1. The science proposed in the OMD program justified the costs of the project, ($600 million over ten years).

2. There is a 'national need" to address resources potential of the continental margins. Geological and geophysical techniques allow only partial answers and drilling is necessary. The program should not be considered to be only a drilling project since "... drilling is but one of the tools to be used-albeit the most spectacular and most expensive."

3. Advances will be needed in technology but they are possible, e.g., riser development; well control (blow out prevention), and improvements in ship and drilling operations.

4. Foreign participation should be encouraged and be managed in a similar fashion to the Deep Sea Drilling Project.

ENGINEERING STUDIES IN SUPPORT OF ACHIEVING THE OCEAN MARGIN DRILLING SCIENTIFIC OBJECTIVES

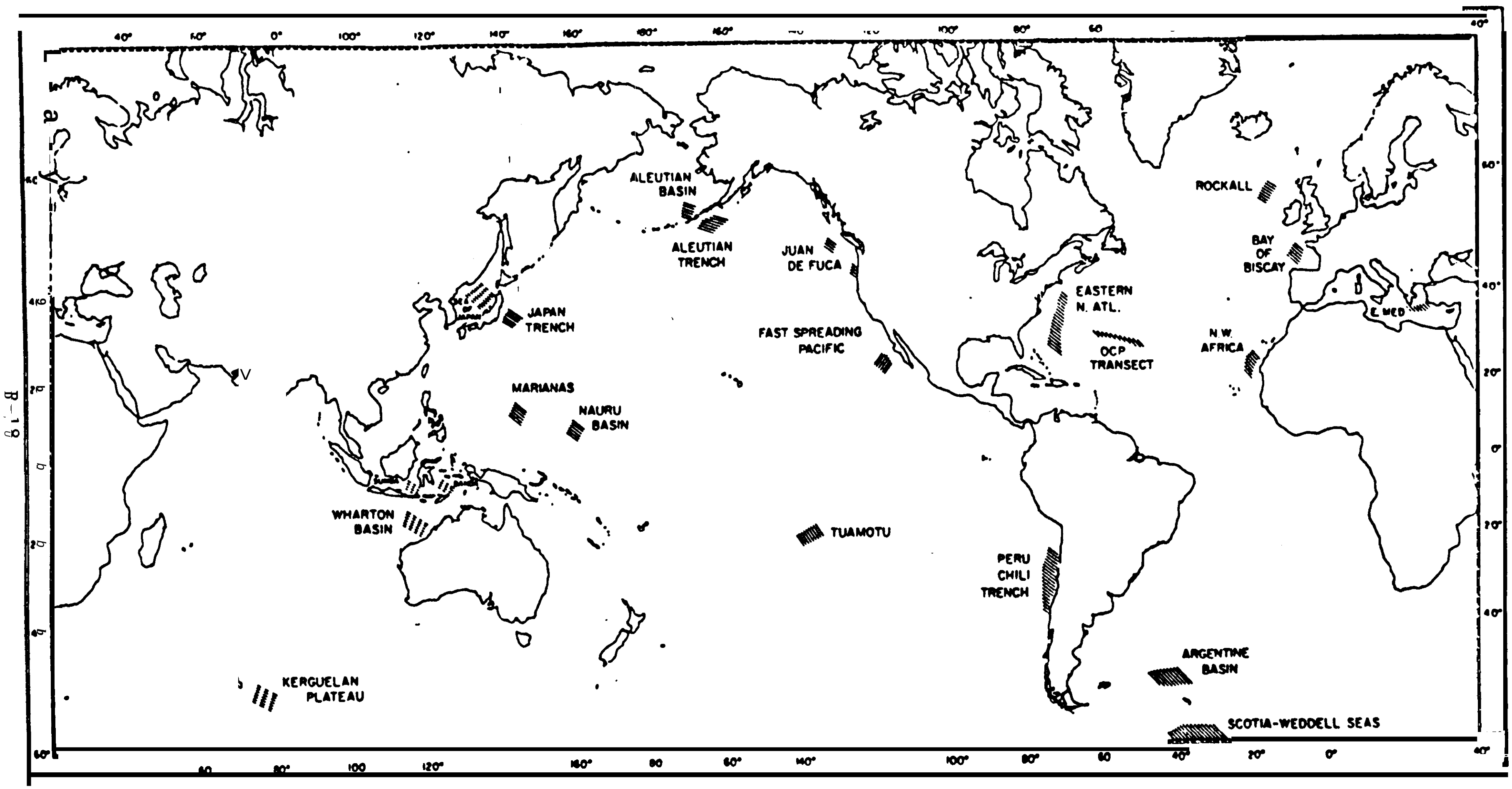
Engineering studies have been conducted during the past several years to determine the vehicle and systems needed to accomplish the drilling tasks and associated work required by the scientific objectives. Although the first of these studies was initiated prior to the establishment by JOIDES of the FUSOD subcommittee, the drilling requirements and the principal characteristics inherent in a drilling vessel have not been altered substantially over the period covered by these studies.

Central to these studies was the requirement for blowout prevention, to provide the capability to control unwanted flows of formation fluids, mainly possible reservoired oil and gas; this prudent necessity arises because of the scientific requirement to drill and sample thick sediment accumulations near the continents. The technical solution is a deep sea riser, providing return circulation of drilling fluids and control access to blowout prevention valves and shutoffs. This same system provides other advantages, such as improved hole stability and improved drill cutting removal; these advantages are applicable to other drilling than in thick sediment sections.

Studies have so far been based on a series of sites to be drilled in five broadly representative geographic areas. These areas (U. S. Atlantic Coast off Cape Hatteras and Cape May, off Cape Flattery, Washington, off Lisbon,. Portugal; off Spanish Sahara-Mauritania border; Sea of Okhotsk-Kurile Island area) were chosen as a model drilling program from possible areas of riser drilling interest. They were chosen to create a substantial latitudinal range, (Okhotsk to Mauritania) and to place sites in the lee of major continents, (Okhotsk, Cape May and Cape Hatteras) and also in the lee of major oceans, (Cape Flattery and Spanish Sahara/Mauritania), with respect to dominant weather patterns. The model entertained conditions of weather and sea that would be neither unrealistically placid nor outrageously difficult. It also realistically planned long distances between sites in a program spanning more than one major ocean. Typical sites are shown in Figure 1.

The main conclusions of these studies are that development and use of a deepwater riser are technically feasible, and that the work should be accomplished from a large single hull drilling ship of the order of a little less than 600 feet length.

Recently, added to these inputs as a special technical solution, was the feasibility of converting the *GLOMAR EXPLORER* from a heavy lift vessel to an oceanographic research drilling vessel, having capability to drill and core the deep ocean basins and margins. The resulting study was extensive, but did not address in depth the necessity to define certain parameters which could affect final design of the system or components. Certain selected systems and components should be subjected to predesign analysis and, where applicable,



TYPICAL SITES OF SCIENTIFIC VALUE IN THE OCEAN MARGINS DRILLING PROGRAM

FIGURE 1

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selected development testing should be accomplished, prior to final system design.

These various engineering studies, and the general conclusions derived in each study, are summarized in the following subsections of this paper.

THE OCEAN RESOURCES ENGINEERING, INC. REPORT

In December 1974, Scripps Institution of Oceanography authorized Ocean Resources Engineering, Inc. to study the technical and economic feasibility of accomplishing the program objectives with conventional exploratory drilling equipment. The scope of the study included:

(a) Determination of the minimum drilling vessel requirements for this program.
(b) Evaluation of oceanographic conditions at several geographical locations.
(c) Comparison of existing or planned drilling vessels to determine what type of rig is best suited for the Ocean Margins Program.
(d) Evaluation of existing marine riser equipment and concepts.
(e] Determination of areas which need development, improvement or extension of existing technology.
(f) Definition of special requirements for logistic support.

The executive summary of the O.R.E. report, "Oceanographic and Vessel Evaluation for IPOD Ocean Margins Study", issued on 26 September 1975, is quoted in part below:

"It is technically and economically feasible to extend the State-Of-the-art technology utilized in conventional exploration drilling operations in order to satisfy these special requirements of the Ocean Margins Program. This program can be accomplished most effectively with a large, dynamically positioned drillship which has an overall length of about 570 feet, a beam of 85 feet and a maximum draft of 24 feet. This unit has the maneuverability needed for widely dispersed drilling areas and has sufficient capacity for storage of riser, drill pipe and drilling expendable. This unit is more suitable and less expensive for the Ocean Margins Program than a semisubmersible or small drillship.

"The most critical item which requires analysis, design, and testing is the marine riser. Existing technology can be extended to meet these needs by commencing a long-range engineering effort in the Fall of 1975. For optimum performance, the drillship should be specially designed with components sized and located as appropriate for these specific operations. This vessel would have the inherent ability to conduct future exploratory oil and gas drilling in deep water. Design and construction of the drillship should commence in February 1977, with mobilization of the vessel accomplished by May 1981. The scientific drilling program can be accomplished in about 4.3 years.

"The Ocean Margins Program may be funded either as a contractor owned, contractor operated program or a government owned, contractor operated program. . . . . The total program costs with the contractor owned equipment are $283 million, while the total costs with the government owned equipment will be only $227 million. Since significant savings can be effected, it is strongly recommended that the drillship be government owned and operated by an experienced offshore drilling contractor."

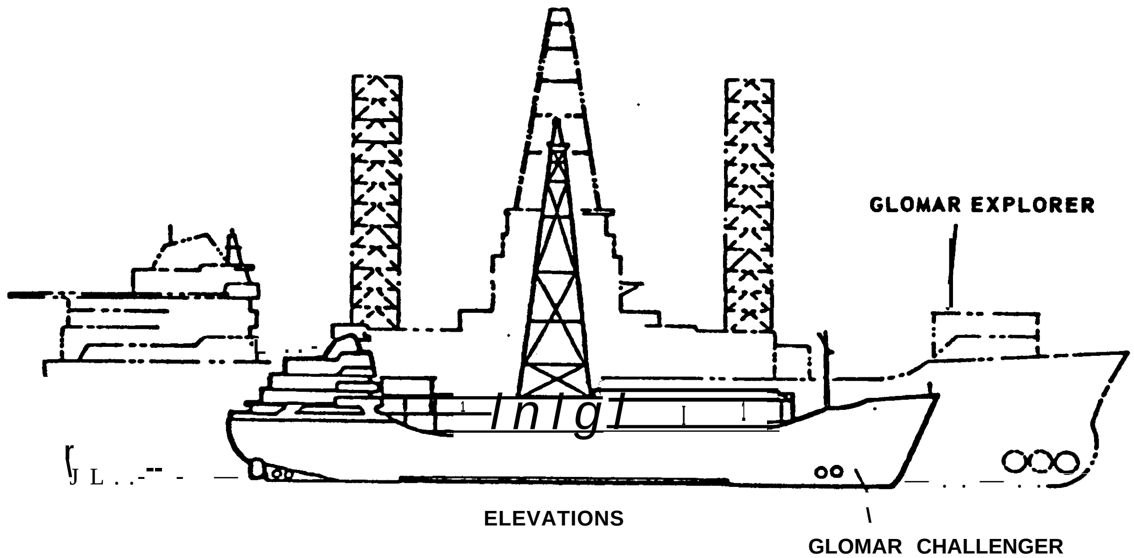
THE GLOBAL MARINE DEVELOPMENT, INC. REPORT

When the GLOMAR EXPLORER became available as a government owned vessel, the Scripps Institution of Oceanography commissioned Global Marine Development, Inc. to study the feasibility of converting this ship from a heavy lift platform to a drilling platform for use in the Ocean Margins Drilling Program. The conclusions derived from this study were presented in a report 'Conversion of the GLOMAR EXPLORER into a Deep Water Drilling and Coring Vessel", 28 February 1977. These are summarized below:

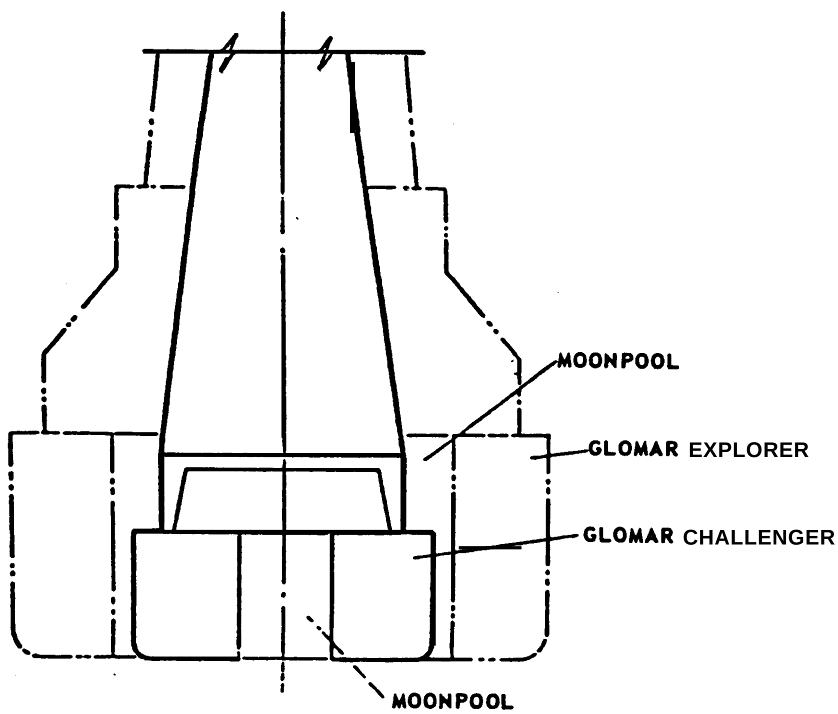
The demonstrated deep ocean performance of the *GLOMAR* EXPLORER, coupled with the present lack of an operational assignment for the vessel, make the U. S. government-owned *GLOMAR EXPLORER* an ideal candidate for the proposed program. GMDI feels especially confident in the feasibility of using this vessel for the proposed program. This confidence stems from our role as prime contractor for this ship from its conception through detailed engineering and construction, subsequent "at sea" operations and ultimate lay-up in the U. S. Reserve Fleet.

The versatility and flexibility of this ship due to its inherent size advantage over the *GLOMAR CHALLENGER is* graphically depicted in Figure 2.

	EXPLORER	CHALLENGER
DISPLACEMENT, LIGHT	21000 TONS	4303 TONS
LENGTH	618 FT.	400 FT.
BEAM	116 FT.	65 FT.
DEPTH	51 FT.	27 FT.
HULL VOLUME	3000000 CU FT.	600000 CU FT.



ELEVATIONS



MIDSHIP SECTIONS

SIZE COMPARISON OF GLOMAR EXPLORER AND GLOMAR CHALLENGER

FIGURE2

Significant conclusions from this study are:

- The GLOMAR EXPLORER can, with minor modifications, maintain position for deep water drilling as well as, or better than, existing "large" drilling ships.
- The vessel motions are less than those of "large" drilling ships operating under the same environmental conditions.
- The vessel has more than adequate stowage capacity for the specified operation. At sea resupply should not be necessary for legs less than 150 days except for crew change.
- Weather downtime at the specified operating sites, is expected to be less than two percent assuming operation does not take place during the favorable seasons at the specified sites.
- The large vessel size allows all specified laboratory and scientific accommodations to be incorporated either in permanent spaces or temporary vans. There is additional capacity available to increase these facilities if desired.
- The unique heave compensated gimbal system allows support and tensioning of the riser such that the riser will not require any type of flotation. This capability obviously simplifies the riser itself as well as all associated handling and support equipment.
- Handling of the drill pipe sections from the storage area to the moving gimballed rig floor at acceptable rates can be accomplished.
- The vessel is already in the U. S. Government inventory. Therefore, the cost of operating the vessel, on a day rate basis, is comparable to other contractor-owned "large" drilling ships.

THE DONHAISER MARINE, INC. REPORTS

The National Science Foundation contracted with Donhaiser Marine, Inc. (DMI) to conduct a comparative review of the O. R. E. report and the GMDI report as well as to draw conclusions from these and other input information regarding the engineering approach that should be taken by the Foundation and to estimate the costs that would be incurred in the engineering aspects of the program. DMI presented its conclusions in three reports issued from July 1978 to November 1978. The conclusions of these reports are summarized in abbreviated form below:

- The most cost effective method of carrying out the Ocean Margins Drilling Program will be for the government to own a suitable drilling vessel, riser and well control system, drill pipe and related equipment and contract for its operation. The total difference in cost over a five year program utilizing the modified GLOMAR EXPLORER, contractor operated as compared to contracting for a contractor owned new drillship will be in the order of magnitude of 160 millon dollars based on 1978 dollars with an 8% per year escalation.
- The GLOMAR EXPLORER, with suitable modifications, appears to be a feasible and financially attractive Ocean Margin Drilling vessel.
- Due to the large size (over twice the displacement of present large drillships) the GLOMAR EXPLORER will have relatively low motion response characteristics which should result in a low percentage of operation downtime due to weather in most geographic areas of the world.
- The vessel has ample storage capacity for the anticipated operation. With modification, the vessel will have a capacity for carrying expendable in excess of that required for carrying out the proposed program missions.
- All of the initially specified laboratories and scientific accommodations can be incorporated in the vessel with ample additional capacity for expansion of these facilities if desired.
- The vessel can be readily modified to incorporate conventional systems for storage, handling and deploying the necessary riser,

casing and drill pipe required for the proposed Ocean Margins Drilling Program.

o The vessel has ample installed generating capacity to provide the necessary power requirements for drilling and stationkeeping. However, initial studies indicate marginal or possibly inadequate stationkeeping performance during the passage of weather fronts, squall lines, and thunderstorms due to limitations of present thrusters and main propellers but modifications can be made to thrusters and main propellers to provide ample thrust to maintain station for the short-term severe environmental conditions.

o The vessel's transit speed which is approximately 12 knots is sufficient for carrying out a world-wide scientific coring program.

o Generally, due to the GLOMAR EXPLORER'S size, present arrangement, elaborate equipment and recent construction, we see no reason why this vessel cannot be modified to provide one of the finest dynamically positioned drillships afloat today. AIso, due to the fact that structural, piping and electrical modifications necessary for installation of required drilling and riser handling equipment will not be of a major nature, it should be possible to convert the GLOMAR EXPLORER to a modern, high capacity, drilling and coring vessel for a small fraction of the cost of building a new drillship of comparable size and capacity.

o Both the ORE buoyed riser concept and the GMDI non-buoyed riser concept appear to be technically feasible; i.e., no insurmountable technical problems have been identified to date. However, both concepts would require additional design studies to arrive at an optimized design and fully identify and correct potential problems. The DMI preferred riser design concept is the buoyed riser.

In the Spring of 1978, the National Science Foundation requested the Marine Board-Assembly of Engineering of the National Research Council/National Academy of Sciences to conduct an in-depth review of the background, scope, and proposed plans for drilling into the deep reaches of the ocean for scientific purposes. Although the review was to be oriented primarily to the engineering aspects of the problem, the committee formed to conduct the review comprised individuals with expertise in ocean geology, seismology, marine engineering, offshore resource recovery, ship design and navigation, and political, environmental, and management matters.

Specifically, the committee was charged by NSF to:

- Relate the technology for drilling and obtaining core samples in the deep ocean to the objectives of the proposed scientific program, (e.g., depth, penetration, environmental forces) with particular emphasis on the technical feasibility, capability and prospects of overcoming deficiencies.
- Consider alternatives to drilling to achieve the program's objectives.
- Examine particularly the riser and well control systems, and related technology including the probable environmental effects of system failure, and costs of these systems.
- Assess the options and costs of alternative drilling platforms.
- Compare the costs of various methods by which the program's objectives could be met.
- Assess the relationships between the Federal government and the drilling industry, as well as among government agencies, as they relate to deep sea drilling.

Over the course of its review, the committee analyzed all of the scientific reports listed in the previous section and all of the engineering reports described above. An interim report was issued in November 1978 and the final report "Engineering for Deep Sea Drilling for Scientific Purposes" was delivered to NSF in April 1980. The recommendations contained therein are quoted below:

"The committee developed several specific recommendations for NSF action in its proposed continuation of deep sea drilling for scientific purposes.

These recommendations are generally couched in terms of the use of *EXPLORER* and the goals of penetrating 20,000 feet of sediments at water depths of 13,000 feet. Despite this, the committee considers essentially all of the recommendations to be equally pertinent to other possible platforms and drilling-penetration or water depth goals. In essence, the committee rec-comends that:

- NSF establish a strong management team to control and guide the program and to maintain close industry contacts to ensure that the required technology is developed.
- The program be operated and the equipment be developed using a systems-engineering approach as outlined in this report and its Appendix B.
- Adequate time and funds be allocated for a thorough preliminary engineering study of at least two years duration prior to converting the ship or fabricating any major equipment.
- In the drilling-system design, early attention be given to the major critical design issues--well control, riser handling, casing programs--enumerated in the body of the report.
- The budget be reviewed and modified to include the cost of additional equipment, data gathering, acquiring and training a crew, and geophysical surveys, and to account for more realistic estimates of inflation.
- Increased effort be devoted to collecting and analyzing, for engineering design use, as much meteorological, oceanographic, and ocean-floor geotechnical data as possible in the broad geographic areas of concern to the program. Further, this effort should be extended as early as possible to acquiring similar data for specific smaller areas as the site-selection process narrows down the areas under consideration.
- Undertake adaptation of existing and development of new logging and downhole measurement equipment to improve the

safety of drilling operations and to lessen the scientific impact of the anticipated reduction in core recovery from deep-penetration holes.

0 Include funding for improved coring equipment and techniques for sedimentary and igneous rocks in the initial system design and development effort.

0 Early attention be given to personnel recruitment and training, so that key operational personnel can help design and develop both equipment and procedures. This includes the concurrent development of computer-based drilling simulators for initial use as design aids and training tools and later use for problem-solving and continued training."

NATIONAL SCIENCE FOUNDATION MANAGEMENT OF THE OCEAN MARGINS DRILLING PROGRAM

As the government manager of the Deep Sea Drilling Project, the National Science Foundation encouraged, participated in, and funded the intial scientific and engineering studies that resulted in the FUSOD report, the O. R. E. report and the GMDI report. Similarly, the DSDP management, in response to the recommendations of these reports, convened the *Ad-Hoc* Group for Future Scientific Drilling and contracted with Donhaiser Marine, Inc. to review the scientific and engineering aspects of the program. Additionally, with support from ONR and USGS, the National Academy of Sciences Ocean Ociences Board was requested to review the scientific program and the Marine Board was requested to review the engineering program.

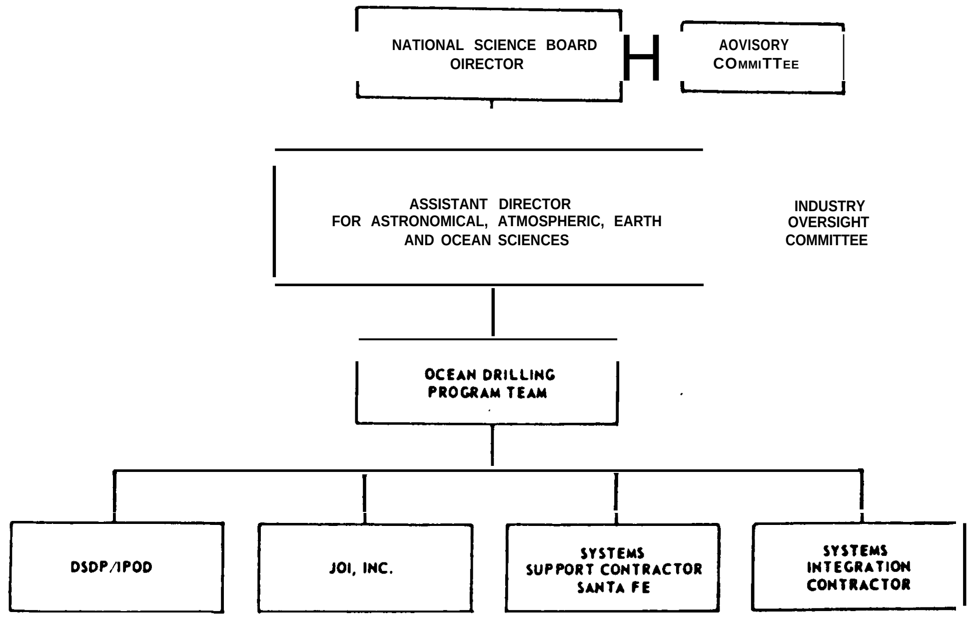
DEVELOPMENT OF A MANAGEMENT STRUCTURE

The input that NSF received from all of these committees and advisory groups not only helped to formulate the scientific" and engineering programs but also provided suggestions as to the level of funding required and as to how the OMD program should be managed. Finally, the Blue Ribbon Committee report strongly supported the program and also recommended that it be funded with add-on or new money in the NSF budget and that it be given high priority; foreign participation was also encouraged.

A final impetus was given to the program when President Carter, at the urging of his science advisor Dr. Frank press, invited members of the oil industry to participate in the project on a cost sharing basis with the government. Subsequent negotiations resulted in the agreement by a number of oil companies to share 50% of the total program costs for the initial phases with the option to continue for the total program. Thus, if the oil companies remain satisfied with the program plans and progress, the cost to the government will be only half what it otherwise might have been.

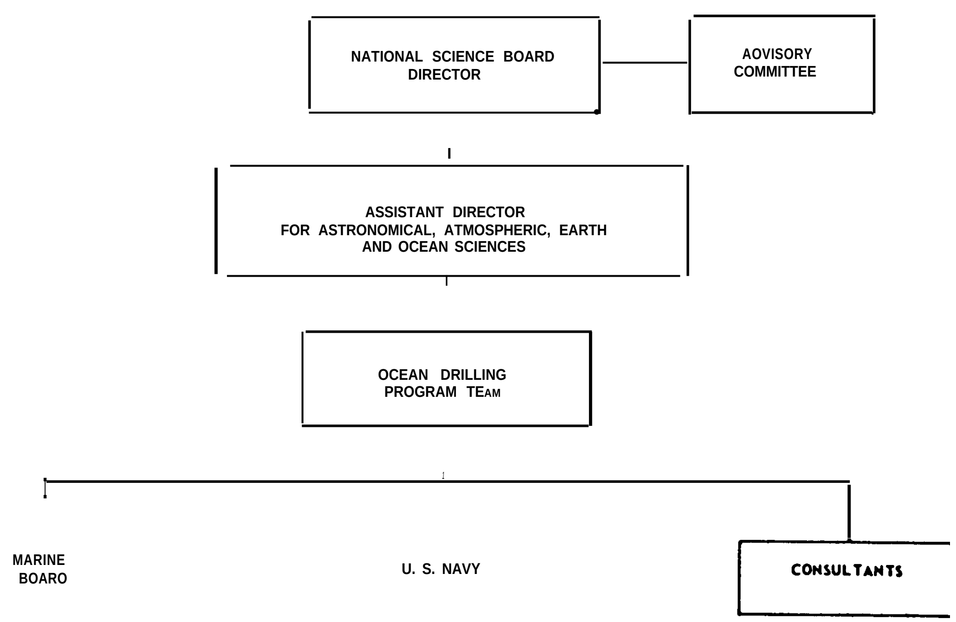
As a result of the inputs from the scientific and engineering studies, the recommendations of the Blue Ribbon Committee, and the prospect of sharing the cost of the program with the oil industry, a revised management structure was established within the NSF to adapt prior management concepts to existing programs and to the Ocean Margins Drilling Program. This structure is delineated in Figure 3. It should be noted that the Advisory Committee to the Director and the Industry Oversight Committee, the latter comprising oil company representatives, are in the process of being established. Using funds from the current budget, the Systems Support Contractor, Santa Fe Engineering Service Company, is presently under contract to NSF; the Systems Integration Contractor, who will be responsible for system design, construction, and operation, will be selected after the program has been specified in sufficient detail to prepare formal invitations to bid. Scripps is presently under contract for the continuing DSDP/IPOD project and JOI, Inc. is also formally participating in the project on a contractual basis.

In addition to the basic program management by NSF, there are being established groups of advisors who will advise both the Director and the Ocean Program Drilling Team. The structure of these advisory bodies is shown in Figure 4. The OMD Advisory Committee will be made up of 40% industry representatives, 40% from academia, and 20% from the public sector. The Marine Board of the National Research Council has already selected a smaller advisory group from among those who served on the 1978-1979 Committee. The Navy is to be called upon for its expertise in ship conversion inspection and supervision. Additional consultants from government and industry will be called upon as required for assisting in various facets of



NATIONAL SCIENCE FOUNDATION MANAGEMENT STRUCTURE FOR OCEAN DRILLING PROGRAM

FIGURE 3



NATIONAL SCIENCE FOUNDATION ADVISORY STRUCTURE FOR OCEAN DRILLING PROGRAM

FIGURE 4

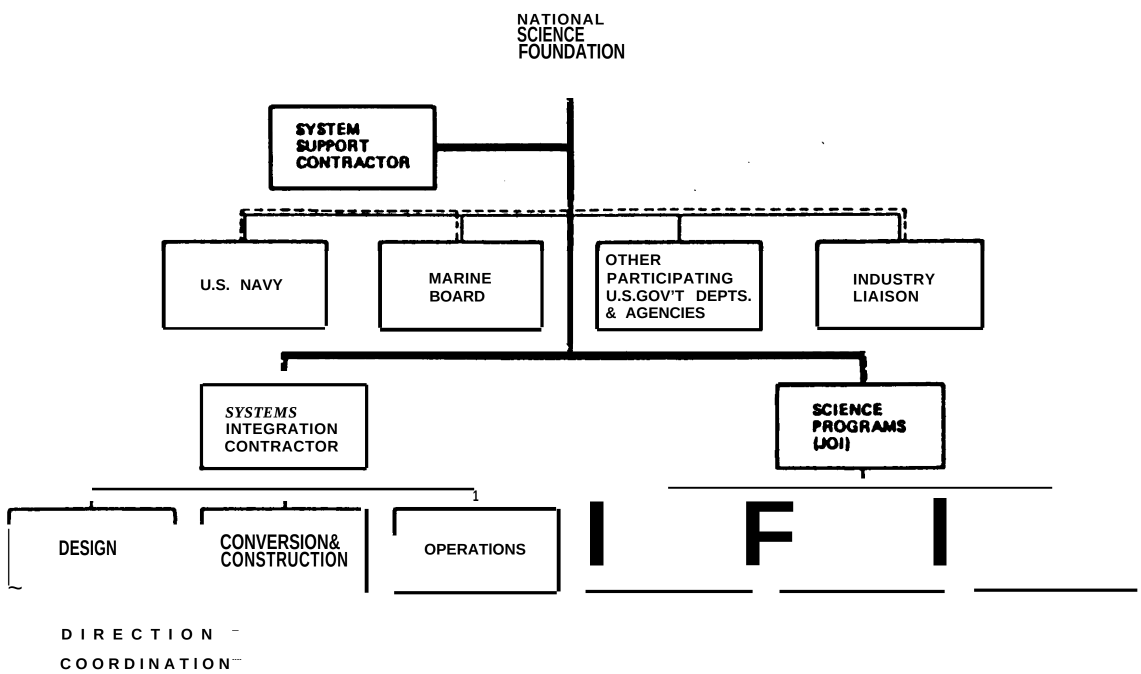
the program as it develops. Figure 5 illustrates the lines of responsibility intended to apply to this combination of management, advisory, and performance groups.

EVOLUTION OF THE OMD PROGRAM BUDGET

Although cost data were included in the FUSOD report, the O. R. E. report, and the GMDI report, these costs rapidly became outdated as inflation took hold, as the scope of the scientific program expanded, and as the engineering ramifications of drilling in the selected sites became more obvious. Revised cost estimates were made by Donhaiser Marine and the Marine Board also made some cogent comments on the cost implications of drilling with a **riser in 20,000 feet of water.**

When Santa Fe, the NSF Systems Support Contractor, was brought aboa one of **their initial tasks was to conduct a more detailed review of the** budget **picture and to relate expenditures to a realistic development and drilling schedule and to anticipated rates of inflation.**

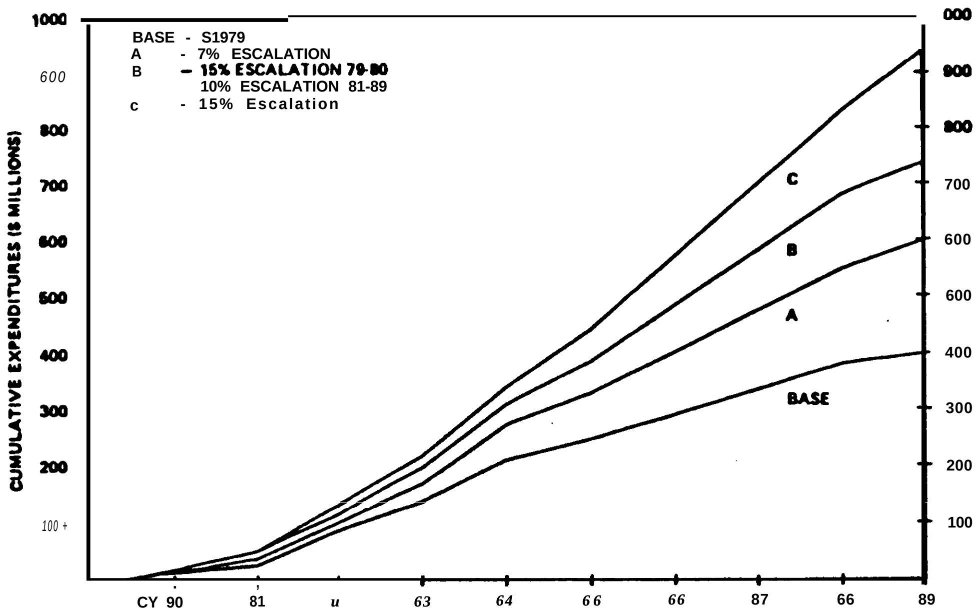
As a. result of this review, the program cost through fiscal year 1989, at a 7% escalation, was estimated to be $615 million which exceeded by $57 mi



OCEAN MARGINS DRILLING PROGRAM RESPONSIBILITY MATRIX

FIGURE 5

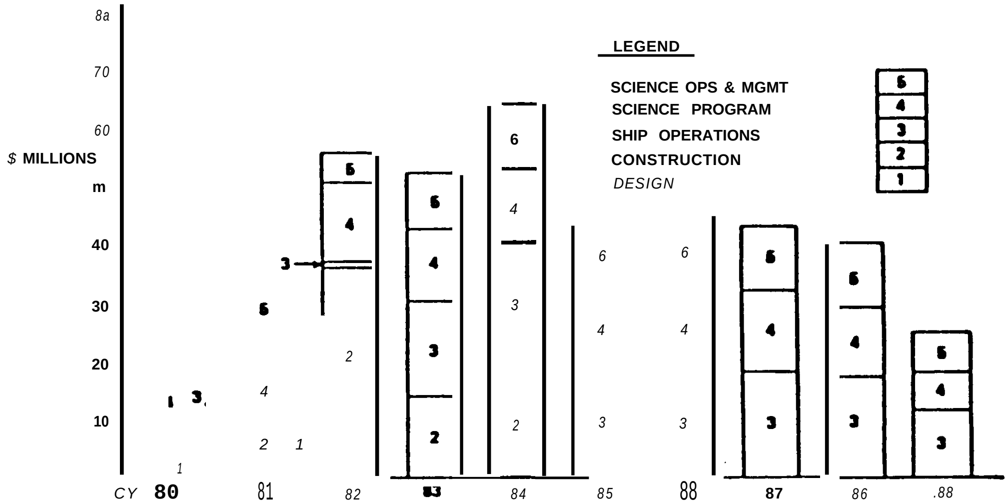
CY	80	81	82	83	84	85	86	87	88	89	PROGRAM
1.0 OMD PROGRAM, 79$	5.3	22.0	56.1	53.8	66.4	46.1	46.8	44.6	42.3	26.8	410.4
ESCALATION @ 7%	.3	3.1	12.6	16.8	26.8	23.1	28.4	32.0	35.6	26.0	204.4
TOTAL @ 7% CASE A	5.6	25.1	68.7	70.6	93.2	69.2	75.3	76.7	78.0	52.8	615.2
ESCALATION @ 15%-10%	.8	5.7	21.9	28.6	45.4	39.3	48.7	55.5	62.3	45.9	343.8
TOTAL @ 15%-10% CASE B	6.1	27.7	78.0	82.4	111.8	85.4	95.5	100.1	104.6	72.7	764.4
ESCALATION O 16%	.8	7.0	29.1	40.4	67.2	60.6	77.9	92.0	106.9	81.7	663.6
TOTAL @ 15% CASE C	6.1	29.0	85.2	94.2	133.6	106.7	124.7	136.6	149.2	108.5	@73.@



OCEAN MARGINS DRILLING PROGRAM CUMULATIVE EXPENDITURES

FIGURE 6

the last previous cost estimate made. This was based upon a total cost in 1979 dollars of $410 million which is used in later cost comparisons. On the other hand, if the escalation average out to 10%, the total cost would be $694 million. Furthermore, if the escalation were initially 15% and decreased within two years to 10%, the total cost would be $764 million. The cumulative expenditures represented by these various hypothesized escalation rates are shown in Figure 6. Figure 7 shows the annual distribution of the base cost of $410 million by calendar year and by program phases in both graphic and tabular format.



CY	60	81	82	83	84	85	86	87	86	89	TOTAL
1.1 PROGRAM SUPPORT. 79S	4.2		–					–			4.2
1.2 EXPLORER CONVERSION. 79S	.6	9.2	36.7	148	22.5			–			83.7
1.3 DRILLING OPERATIONS. 70S		1.2	6.4	25.8	30.3	31.8	31.8	31.8	30.7	20.7	210.8
14 SCIENTIFIC PROGRAMS. 79S	.5	11.6	13.0	13.2	13.6	14.3	150	12.8	11.6	6.1	111.7
1.0 OMD PROGRAM. 79s	53	22.0	56.1	53.8	66.4	46.1	46.8	44.6	42.3	26.8	410.4

GRAPHIC AND TABULAR DISTRIBUTION OF PLANNED EXPENDITURES

FIGURE 7

Currently, the total program funding figure being used for discussion is $700 million of which $350 million will be supplied by the government and $350 million by industry. Although the curves of Figures 6 and 7 show these expenditures being made over calendar years 1980 through 1989, it is anticipated that the program will move somewhat more slowly at the beginning with a consequent stretch-out to calendar year 1990.