Ocean Margin Drilling

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OCEAN MARGIN DRILLING

A TECHNICAL MEMORANDUM

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PREFACE

This Technical Memorandum was prepared in response to a request from the Chairman and the Ranking Minority Member of the HUD-Independent Agencies Subcommittee of the Senate Appropriations Committee. The Committee requested that OTA conduct an evaluation of the Ocean Margin Drilling Program, a major new public-private cooperative research effort in marine geology proposed by the National Science Foundation. They were particularly interested in the scientific merits of the program and whether other, less costly alternatives could yield the same or greater scientific return.

Because OTA already had a more general ongoing study of ocean research technology, the agency was able to respond quickly to this request. The Memorandum was prepared with the advice and assistance of a small panel of scientists plus a much broader group of scientists, engineers, petroleum company representatives, and others who submitted material for our use and reviewed our draft report. The study discusses the scientific merit of the program, possible alternatives to the present program plan, problems associated with technology development, aspects of petroleum company participation in the program, and government management considerations. There are also appendices including specific alternatives proposed by the OTA panel members and historical factors leading to the present plans.

JOHN H. GIBBONS

Director

OTA Staff for Review of the Ocean **Margin Drilling Program**

Robert Niblock, Ocean Program Manager

Peter A. Johnson, Project Director

Prudence S. Adler
Kathleen Beil
Carolyn Gilmore

Consultants

John Andelin
Denzil Pauli
Robert Taggart

Advisory Panel for Review of the Ocean Margin Drilling Program

Dr. Joseph Curray
Scripps Institution of Oceanography
University of California
La Jolla, California 92039

Dr. Charles Drake
Dean of Graduate Studies
Dartmouth College
Hanover, New Hampshire 03755

Dr. James Hays
Professor of Geology
Lamont-Doherty Geological Observatory of Columbia University
Palisades, New York 10964

Dr. John Imbrie
Department of Geological Sciences
Brown University
Providence, Rhode Island 02912

Mr. Feenan Jennings
Director, Sea Grant Program
Texas A & M University
College Station, Texas 77843

Dr. John Sclater
Department of Earth and Planetary Sciences
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dr. Tjeerd H. van Andel
Geology Department
Stanford University
Stanford, California 94305

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Dr. Albert Bally
Shell Oil Company

Dr. Kevin Burke
State University of New York at Albany

Mr. Joseph Carter
Gulf Oil Company

Mr. John H. Clotworthy
Joint Oceanographic Institutions Inc.

Dr. Edgar S. Driver
Gulf Research & Development Company

Dr. Howard Ellinwood
Standard Oil of California

Mr. John I. Ewing
Woods Hole Oceanographic Institution

Dr. Terry N. Gardner
Exxon Production Research Company

Dr. Glen Hager
Continental Oil Company

Dr. William Hay
Joint Oceanographic Institutions Inc.

Dr. Hollis Hedberg
Princeton University

Dr. Claude Hocott
Gulf Universities Research Consortium

Dr. Charles D. Hollister
Woods Hole Oceanographic Institution

Dr. Doyle Marrs
Mobil Oil Corporation

Dr. Arthur E. Maxwell
Woods Hole Oceanographic Institution

Dr. Donald McIvor
Exxon Corporation

Dr. H. William Menard
U.S. Geological Survey

Dr. Theodore C. Moore, Jr.
University of Rhode Island

Dr. George B. Pichel
Union Oil of California

Dr. Allan Riley
Standard Oil of California

Mr. Wilbur G. Sherwood
National Science Foundation

Dr. William H. Silcox
Standard Oil of California

Mr. W. H. Smith
Phillips Petroleum Company

Dr. Walt W. Steiner
Atlantic Richfield Company

Mr. James Thompson
Sunmark Exploration Company

Dr. Peter Vail
Exxon Production Research Company

Dr. Peter Wilkness
National Science Foundation

Dr. Edward L. Winterer
Scripps Institution of Oceanography

A Review of the Ocean Margin Drilling Program

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1. Introduction

An important new scientific endeavor to improve our basic understanding of the nature and origin of the earth has been under consideration for the past several years. And now the National Science Foundation (NSF) is prepared to begin a $700 million, 10-year program of marine geologic investigations. This effort, known as the ocean margin drilling (OMD) program, resulted from years of planning and evaluation by government-sponsored committees and represents an innovative approach to mutual efforts by government, universities, and the **industry.** The program is both a continuation of deep ocean drilling under NSF earth sciences and a new thrust to investigate the geology of continental margins and ocean crust where very deep drilling is necessary to penetrate unknown regions. Some of the margin regions, which are the borders between continental shelves and the deep ocean, could contain substantial oil and gas resources, but very little evidence has yet been collected.

Early planning for an ocean margin drilling program began in 1973 and continued with the Conference on the Future of Scientific Ocean Drilling (FUSOD) held in Woods Hole, Massachusetts in 1977. In 1978, an NSF advisory group reviewed the scientific merit of a margin drilling program and in 1979 an NSF “blue ribbon” committee addressed the national interest in such an effort. Recently, an NSF sponsored meeting was held in Houston during the week of March 3, 1980, and included scientists and engineers from academic institutions, petroleum companies, and government agencies. At this meeting, an ocean margin drilling model program plan was developed. That plan, the principal current description of NSF’s ocean margin drilling program, is what this report addresses. Engineering considerations and scientific objectives were evaluated in that plan. A model program that would consist of six years of drilling and four years of pre-drilling preparation was presented. The plan also presented an estimate of program costs* The model drilling program includes 10 sites and 15 holes. The deepest holes in the model program are about 21,000 feet below the sea floor in about 11,000 feet of water. Two sites are in the Pacific, one in Antarctica's Weddell Sea, and the others in the Atlantic and Gulf of Mexico. The scientific objectives stated in the plan are to investigate: (1) passive and active continental margins; (2) the earth's crust beneath the deep ocean and (3) the deep sea sediments which could yield historic environmental information on the earth, especially the opening of the Atlantic Ocean and the Gulf of Mexico.

It is planned that the program will be jointly funded by the Federal government and the petroleum industry, each sharing 50 percent of the costs over the 10 year period. Eight major petroleum companies have expressed interest in participating and they are expected to commit funds for FY81 following a July 1980 meeting to detail NSF's technology plans. These technology plans include the conversion of the government-owned Glomar Explorer to a deep drilling ship and the development of a riser system* for controlled drilling in up to 13,000 feet water depths and up to 20,000 feet below the sea floor. There are some differences between the water and drilling depth goals stated for the model drilling program and for the technology development but these are not considered significant.

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*A riser is a large diameter pipe extending from the sea floor to the drilling ship on the surface through which the drill pipe is inserted. The riser acts as a conduit for drilling fluid which is pumped down the pipe and flows back up to the ship between the pipe and riser. The riser is also used to help control pressure in the well and support blowout prevention (see Chapter VI).

This Technical Memorandum reviews the present plans for the Ocean Margin Drilling program and addresses questions on the merits of the program and alternatives to it. It analyzes problems associated with the approach proposed by NSF and suggests possible improvements. It also discusses the institutional capability of the Federal agencies which are to manage this program; the technology development aspects, and the problems and opportunities associated with industry participation.

To prepare this memorandum, OTA assembled a panel of scientists and sought the advice of technology consultants and petroleum company representatives. At a March 33 panel meeting, presentations on the program were made by the NSF and the Joint Oceanographic Institutions Inc. (JOI), which were followed by a discussion of the program's scientific merit and alternatives. Panel members, OTA staff and consultants prepared the material that was used as the information base for this document. The report was reviewed by science and industry experts listed in the acknowledgements and appropriate comments were incorporated.

II. Summary of Findings

OTA analyzed the National Science Foundation's plans for its ocean margin drilling program. These plans are not yet complete, but they have resulted from a substantial effort over the past several years by government, industry and academia to develop a major, important new thrust in earth and ocean sciences. The OTA findings are based on a relatively brief review of these plans, and rely heavily upon the advice of scientific and industry specialists having considerable experience in the field.

The following are principal findings derived from our review.

1. The NSF plan for ocean margin drilling developed in March 1980 contains many worthwhile scientific objectives; the drilling plan and sites chosen encompass significant scientific investigations and are in keeping with past committees' recommendations. It is a distinct improvement over previous ocean margin drilling plans. The plan is, however, a considered compromise which was developed considering such constraints as the use of an Explorer-type vessel and drilling only in water deeper than 6,000 feet. While most scientists agree that the compromise is a reasonable one given the constraints, many question the wisdom of the constraints.

2. The ocean margin drilling plan is supported by NSF and the Joint Oceanographic Institutions (JOI) who assisted in its development. However, there is not a broad scientific consensus on the present program. Since it has been less than three months since the March 1980 NSF plan was prepared,

neither a detailed document nor a peer review process has been developed. A more explicitly defined and executed peer review process in the future would help to build a consensus. Holes, sites and objectives are likely to change as the technology and other plans are developed in the future, and additional scientific review will be necessary to assure broad support and proper attention to high priority scientific problems.

3. A major concern of many scientists is the lack of specific plans for geophysical investigations that must preceed the drilling. However, a planning effort did begin after the March **1980** meeting.

4. The probability of achieving the scientific objectives through the holes drilled and information collected will, in large part, be determined by the capabilities of the technology developed. The technology for controlled drilling 20,000 feet beneath the ocean bottom in about 13,000 feet of water is not yet developed. Some of the deep holes may not be completed as planned because of the technological uncertainty associated with deep ocean drilling in as yet unknown environments. Engineers and scientists will undoubtedly need to make compromises as the program proceeds which may result in either lowering of the ultimate scientific objectives or significant cost escalations. Both academic and industrial scientists are concerned that additional costs to develop deep drilling technology could be diverted from other science funds which are not yet fully defined or from other NSF ocean science programs.

5. The potential for oil and gas resources in the continental margins is a subject of much speculation, but competent geologists claim that these areas hold significant promise at least to the extent that they should be carefully explored. The ocean margin drilling program would provide better scientific information on which to base further speculation on oil and gas resources, but it is not a logical oil and gas exploration program. Some petroleum companies have claimed that they are not participating because the program is not adequately directed toward assessing commercial resources. Others claim they expect the scientific benefits to help them in the long run.

6. The National Science Foundation has successfully directed the deep sea drilling project over the past ten years, however, NSF has used an established oceanographic institution to carry out the day-to-day management. The ocean margin drilling program represents a major increase in money and a new thrust in technology development, not a simple expansion of previous efforts. The capability and appropriateness of NSF in managing such a program has been questioned by some scientists and engineers. Their questions include: whether NSF can effectively manage the considerable technology development work; whether the oil and gas resource aspects would dictate more direct involvement by DOE or USGS; whether the science benefits are overshadowed by the technology development benefits and whether the relative contribution of each participant is equitable.

7. The petroleum company participants are expected to decide this July whether to support the first year's efforts. Most of these participants support the program because they believe it will result in progress in science and have some secondary benefit to their interest in

subsea hydrocarbon resources. Many companies are concerned about their liability as participants in the program, about anti-trust problems that may develop and about the level of funding required by each. They believe that more companies need to be involved if they are to support the effort past the first year. Some believe the cost estimates are too low for the technology now planned.

8. A more sharply focused science program with fewer options than the present plan is advocated by several of the scientists OTA contacted. They have suggested alternatives which might result in lower initial costs and a postponement of the decision to fund major technology developments. Many of these alternatives include an approach to first identify those drilling targets which are within present technical capabilities. Other alternatives could be developed with a greater emphasis on hydrocarbon resources (and thus industry involvement) but would probably require considerable changes in government practices in leasing offshore lands for oil and gas exploration (see Section IV and Appendix A and C).

III. Scientific Merit of the Planned Program

A. Scientific Objectives and Priorities

The proposed ocean margin drilling (OMD) program is large and monolithic compared to most earth (oceans and solid earth) science programs run by the National Science Foundation (NSF). Even if the total annual expenditure is not so large compared with the aggregate of all other programs that could be labeled earth science, the others are divided in many packages and supported by individual constituencies. While oceanographers, geologists, geophysicists, and other earth scientists should agree that this program be assigned very high priority, no such consensus has apparently yet been achieved.

The present plans, developed March 3-6, 1980, are based on advice from expert representative groups of scientists and engineers. But questions have been raised relating to determining scientific objectives and to the **inevitable compromises** that result from trying to satisfy many interests within budget constraints.

Most scientists agree that the presently planned program is a good compromise given the constraints that appear to be governing. The constraints were developed by the program planners from the following assumptions:

- The Glomar Explorer is a valuable national asset and it should be a cost-effective platform for deep ocean drilling.

- The passive ocean margins should **receive** high priority for scientific investigation because they are a geological frontier **that might contain oil and gas resources.**

- **The petroleum industry and NSF will share in funding and program** planning.

The scientific experts planning the Explorer drilling **program were not** asked "what is the most important science we need to do in **the field of** geology and geophysics." Rather, it was "what is the most important science you can do with an Explorer-type vessel given the constraints that: a) most of the work is on passive margins; b) drilling is deeper than 6,000 feet water depth (but not much deeper in the early phases); and c) most of the margin drilling is on U.S. margins." These are different questions, and the implication that a new program had to be done according to these constraints was given to those who prepared the most recent scientific plans.

Many **believe that the recently developed plan contains many worthwhile scientific objectives -- the drilling plan and sites chosen encompass significant scientific investigations that are in keeping with past committees' recommendations. It is a first step towards defining of a complete program that was lacking in previous plans. However, some are concerned that the entire program is too diffuse and attempts to accomplish too many goals -- these scientists advocate a more narrowly concentrated effort.**

Many scientists agree that the present OMD program is probably the broadest scientific program that could be put together using the Glomar

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Explorer in an industry-academic-government cooperative venture. However, many scientists believe that it may not be the best, the most appropriate, or the most important scientific program that could be proposed for exploring the oceans floor.

Whether scientific objectives can be achieved from the holes drilled and information collected will, in large part, depend on by the capabilities of the technology developed. Some deep holes may not be completed as planned because of the uncertainty associated with deep drilling in as yet unknown materials. Engineers have estimated a 50 percent probability of completing all the planned holes. As the technology is developed, better estimates of success probabilities for each hole can be made, but it is likely that some deep drilling goals will not be reached.

Also, many scientists see the present program as being too much at the instigation of NSF administrators rather than in response to the requests of the scientific community. They argue that it may result in good technology and give rise to good science, but it does not result in a good or cost-effective scientific program.

However, other scientists argue that, in general, the present plan is worthy of complete support. They state that the scientific objectives are of high priority and that if the petroleum industry provides 50 percent of the funds, the program will be a bargain for science. Some claim that even allowing for the predicted chances of technological failure, each hole or site will offer partial answers to many of the questions asked. They also note that much of the success of past deep-sea drilling has been from unanticipated results.

Because **scientists disagree on the program's goals and scope, it appears important that the peer review process for the scientific program should be more explicitly defined in the future. Since the holes, sites, and** objectives are likely to change as the technology and plans are developed, additional review is necessary to assure broad support and proper attention to high-priority scientific problems.

Since neither a document nor a process for scientific peer review of the program is yet available, OTA identified through its panel some of the more important and specific criticisms of the scientific plan. These fall into three categories:

- Although many good scientific questions are posed, the resources to attack them appear to be spread so thin that important breakthroughs are unlikely to occur. The plan represents a compromise and the product of a large workshop attended by a group of respected scientists.

- The requirement that drilling occur only in water deeper than 2000 meters may rule out relatively simple approaches to important scientific questions and may stifle research in areas of the sea floor having an economically realistic resource potential. Neither the existence of nor the reason for this minimum depth has been made clear. However, OTA has found that the limitation was proposed by the industry participants. This depth limitation is considered by some to be a barrier to developing an effective research strategy.

- To some, the present program gives too little support to academic geophysics and submarine geology. This shortcoming particularly disturbs academic scientists who believe that submarine geology and geophysics led the way to the present revolution in earth sciences. They point out that the academic research fleet is in a crisis state because of budget cuts and the soaring fuel prices, and important new research enterprises in oceanography, including the upgrading of multi-channel seismic programs, hydraulic piston coring, and acoustic tomography lack adequate support.

There is wide agreement, even among those who support the present program, that more emphasis on geophysical surveys is needed. While funds are reserved for "other science," the plan for a science program is lacking. A JOI committee is now planning a geophysics program that includes provisions for scientists to compete for specific projects.

For the program to succeed, the most advanced state-of-the-art geophysical surveying methods and experiments will be needed. If the drilling program is delayed because of reduced funding in the next fiscal year, geophysical research could continue as was proposed in 1979 by the National Academy of Sciences. The NAS report -- "Continental Margins Geological and Geophysical Research Needs and Problems" (known as the "Bally" report) -- recommended that academic institutions should have at least one modern, thoroughly-equipped, state-of-the-art geophysical surveying vessel, as well as the supplementary equipment aboard existing oceanographic ships for conducting multi-ship surveys.

Between now and when the Explorer is ready to begin drilling, the selection of sites and holes should not be frozen. The Houston document presents a drilling plan based on present knowledge. Additional surveying, both as part of and outside this program, will change ideas, concepts, precise drilling sites, and even general drilling regions. Just as the International Phase of Ocean Drilling (IPOD) program remained flexible and evolved with time, so should the OMD program.

B. Discussion of Science Objectives

Some scientists are concerned about past and possible future compromises. The program plan from the recent Houston meeting on ocean margin drilling is a considered compromise. While a major truncation of the recommendations from the 1977 Woods llole conference on the Future of Scientific Ocean Drilling (FUSOD), it takes into account costs, engineering and technology, and the details of associated scientific investigations to a much greater degree. The four areas of investigation -- passive margins, active margins , ocean crust, and paleoenvironment -- raise fundamental scientific questions that drilling could address. As a compromise, the plan provides for a few holes to be drilled in each area type. While the probability of achieving all objectives in each hole is no better than even, that of accomplishing some of the objectives is considerably higher. While, in general, the importance of the scientific results will depend on how deep the holes are drilled, the probability of producing significant results are quite high.

The conclusion that significant scientific results will be achieved depends on several assumptions. These **are:**

- That the schedule will be slowed down in view of budget considerations.

- That the regional geophysical and geological studies necessary to define a problem area, as well as more detailed site investigations needed to pinpoint specific targets for drilling will also have been completed. This is not guaranteed, but if the funding is available, the lead time before drilling is such that they could be done.

- That technological cost overruns, if they occur will not be made up by taking funds away from the scientific investigations.

- That the program is greeted with enthusiasm by the ocean scientists, especially younger ones who will be working with the data.

- That the primary objective of drilling is to gain scientific knowledge rather than to assess commercial resources.

- That the program will not be possible without government-industry-academia cooperation. Given the actions that have taken place to date, this is not an unreasonable assumption. Accepting these three constituencies, the program needs to respond within its budget to their needs.

It would be fair to conclude that the four problem areas -- active margins, passive margins, ocean crust, and paleoenvironment -- have the highest scientific priority in marine geology and geophysics. However, “there are other significant problems, particularly processes in ocean rifts and the nature of very deep continental margins. To sample these regions would require even more advanced technology than that proposed for the OMD program.

Some more specific concerns about the program include:

- The total budget of about $692 million includes $43 million for scientific activities on board the drilling vessel and $118 million for scientific support and site surveys. The $43 million obviously has to be tied closely to drilling operations, but the $118 million does not. The latter sum could be used to meet technological cost overruns. Most scientists OTA contacted believe that a system is needed to make sure that science funds are not diverted.

- Acceptance of the program poses some risks for oceanographic institutions and individual scientists. Many now receive annual support from the petroleum industry. Because of their participation in this program, industry might transfer funds from direct support of oceanographic institutions or individuals to indirect support through the NSF program. The oceanographic institutions may receive ocean margin drilling funds at some cost to their other programs.

- USGS is enthusiastic about the program, but is not providing financial support. USGS is charged with learning about the nation’s geology and making resource assessments. It also owns much of the existing marine geophysical data. It is not clear why USGS is not funding the program.

- The Department of Energy (DOE) is not yet participating financially in the program. Given its responsibilities for energy resources, DOE should be interested in information relevant to industry. The problem may be accentuated by industry apprehensions about the government getting into the oil and gas business.

- One might question the scheduling of the OMD program and what it would be if the Glomar Explorer were not now government owned and idle. No one is apparently against drilling in the four areas selected, but there are major questions of when to drill and what ought to be done first. Considerable lead time is involved in preparing the Glomar Explorer. Even if all of the geophysical and site survey information were available, drilling would not begin for some years. On the other hand, given the present state of geophysical knowledge, a stretching of the schedule for a few years in times of tight budgets may be acceptable.

- Some also argue that NSF should not be too deeply involved in a major marine engineering development program. The goal of this program would be a riser and well control system capable of operating in very deep water. Despite extensive industrial experience with ocean drilling, nothing like this has been attempted before. All of the engineering studies anticipate difficulties that are severe but not insurmountable.

Such an engineering program represents a far greater technological leap than anything accomplished in the _Glomar Challenger_ program, and the type of engineering problems involved in mounting an all-weather, open-ocean operation are very different from NSF's experience with large scientific technology projects on land. The risks to NSF -- and to the scientific community at large -- are substantial. Some view this as a major shortcoming of the program. There is also the view, however, that a major technological push is good for future scientific advancements despite the risks.

IV. Alternatives Proposed

OTA asked its scientific panel to consider whether alternatives to the present ocean margins dril1ing program could increase its scientific value, decrease the costs, or both. Several alternate approaches are included in Appendix A. Nest alternatives first quest ion the basic assumptions or constraints that helped mold the present program: industry participation, technology development, the variety of scientific problems addressed, and the budgetary considerations. The interaction between these factors has produced certain compromises evident in the present program.

Among the alternatives suggested are two genera 1 approaches -- those that place greater focus on the science and those that give greater enphasis to resources.

A. Alternatives With Greater Science Focus

Most alternatives focus on the scientific efforts and recommend a delay in developing the technology, and thus the very deep drilling. While these alternatives luck the scientific variety as the present plan, they suggest focus on a few principal areas of research. Most advocate using the NAS' Bally report, which is broadly supported as addressing important problems, for initiating a program. Some, such as that proposed by Dr. John Imbrie, advocate making a direct connect ion between specific science goals and national needs for future oi1 and gas resources.

The principal elements in an alternative approach with a greater science focus would be to:

- Plan and conduct extensive geophysical surveys as the initial effort and delay decisions on the technology and operations for very deep drilling.

- Identify targets that are within the capability of existing technology for the early drilling efforts.

- Define the goals of the very deep drilling phase after the initial work is completed, assuming the possibility of substantially improved technology by that time developed by industry.

- Seek broad scientific support for specific program plans commensurate with the size of the effort before each phase of the program.

This approach appears to have the following effect on other aspects of the program.

Industry Participation: Some petroleum companies may be more willing to support this approach, others may not if drilling is proposed in water depths of less than 6,000 feet.

Technology Development: This would be done in steps with lower risk at each step.

Budget: Less funding would be required in the early years. More emphasis would be placed on geophysical studies and less on developing hardware. A decision to spend alot more money for the drilling ship may be delayed. Also, it may be possible to estimate more accurately the costs at each phase.

B. Alternatives with Greater Resource Focus

Industry and some academic scientists adovocate the need for a greater understanding of potential hydrocarbon resources in offshore continental margins. The present program offers very little for assessing commercial resources. Some petroleum companies want the government to refrain from any greater involvement in attempts to locate offshore oil and gas resources. However, there is some support for a program that would include some government and industry cooperation with a focus on assessing commercial resources. (See Section VI for industry views and Appendix C for the Hedberg proposal.)

An alternative for this approach would probably contain the following elements:

- The petroleum industry would take the lead in planning and conducting a program to assess the commercial resources on the U.S. continental margins.
- The government would offer incentives to allow industry funding of the program.
- Scientific studies would be conducted both as an adjunct to the industry program and separately in those areas that industry

would not cover.

The approach appears to have the following effect on other aspects of the program:

Science: A new science plan would have to be developed in conjunction with an industry plan. It would be important to get broad support for this as well.

Technology: The Glomar Explorer may be an appropriate vessel for this program, but, if so, the goverment would not be involved in developing advanced drilling and well control technology.

Budget: The government's ocean margin drilling budget would probably be substantially reduced and industry would probably assume the large financial risks.

V. Anticipated Technological Problems

OTA reviewed the effort that will be required to develop the technology for meeting the goals of NSF's current plant for drilling in the ocean margins. Heavy reliance was placed on an April 1980 report by the Marine Board of the National Research Council titled "Engineering for Deep Sea Drilling for Scientific Purposes." That report should be referred to for more detailed evaluations of future engineering problems and uncertainties associated with the NSF program.

The technology to drill 20,000 feet below the ocean bottom in 13,000 feet of water in the continental margin is not yet developed. The ocean margin drilling program contains a significant element of technology development. Engineers and scientists must compromise as the program proceeds, which may lower the ultimate scientific objectives.

The 13,000-foot riser pipe required for some deep margin sites is about twice the depth of existing technology. A major effort will be needed to develop such pipes along with the entire deep drilling and well control system. Basic designs of this system have not been completed or carefully reviewed. The probability of completing the deep hole targets has been estimated at 50 to 60 percent by NSF engineering consultants given existing data. While this will be improved as planning proceeds, it may also be that some holes will not be completed.

Since the technology is uncertain, so are the cost estimates. Because extremely deep holes are very costly, the sites have to be selected with great care and attention to engineering conditions as well as scientific objectives.

A drilling system for the ocean margins will include a large number of complex and interrelated components. All system elements will probably require some modification from present practices to perform at the extreme water depth and penetration goals of the program. Figure 1 outlines the extent of development for major equipment.

The Selection of a Drilling Platform

The ocean margin drilling program needs to develop a suitable drilling platform for controlled deep ocean drilling. The Glomar Explorer, with its very heavy lift capability, has been tentatively chosen as the best platform following studies of its cost effectiveness as well as that of alternatives. The Glomar Explorer is owned by the government. Further work is necessary, however, to design the Explorer conversion and evaluate its suitability more specifically.

Some **petroleum companies and other are still concerned that the Explorer may not be the best or most cost-effective ship to use. One concern relates to the extensive conversions necessary to install a complete deep drilling system. When this conversion is done, some of Explorer's present capabilities will be significantly altered and much of its value as a deep-sea, heavy-lift ship will be lost. The engineering trade-offs on**

Figure 1

DEEP WATER DRILLING TECHNOLOGY/WATER DEPTH SPECTRUM

	To 30&350' WD	To 2000-3000' WD	Today To 4000-5000' WD	To 13,000' WD
Vessel:	Bottom Founded Jock-Up or Submersible or Shipshape	Floater, Semisubmersible 01 Shipshape		Large Shipshap (Glomar ExplorerXE)
Vessel Positioning:	Fixed	Conventionally Moored	Dynamically Positioned	
Riser:	Extended Casing	Bore to 1500' Buoyed beyond 1500' Max. Top Tension: About 640,000 lbs.	Buoyed Max. Top Tension: 1 Million lbs. Storage Hangoff Procedure Multiple Riser Trips Undesirable Riser Handling System Desirable	Buoyed (E) Max. Top Tension: About 1.5 Million lbs. (D) Storm Survival Procedures Necessary (U) Impractical* Necessary(F)
Well Reentry	N/A	Guidelines	Guidelines Remote Re-entry with TV end/or Sonar	Extension of Depth Capability(E)
BOP:	Surface No Remote Control	Subsea - Redundant BOP'S Direct Hydraulic Control	Multiplex ElectropHydraulic Control Subsea Accumulators, Rechargeable from Surface Acoustic Bock-Up Control	Requires Stronger Clamps (U)& Connectors end/or BOP Frame(F) Subsea Hydraulic Power: Source Probably Necessary (U) Extension of Depth Capability (E)
Wellhead Foundation:			Sensitive to Pullout & Side Loads from Riser	Critical (E)
Well Control:	Surface Choke Adequate	Deepwater Kill Procedures Required	Pressure Equalzation Volvo (Available)	Seafloor Choke for Circulating Gas Kick Desirable (D) Probably Necessary (D)

Key: U - Undeveloped; D - Developed but not field tested; E - Extension of existing technology; F - Field tested

" Solution dependent on cosing program and feasibility of extending drilling shallow hole without riser

Source: National Academy of Science, Marine Board, National Resource Council, Engineering for Deep Sea Drilling for Scientific Purposes, Washington, D.C. : 1980

drilling platforms need careful evaluation as soon as the overall system is designed.

General Requirements

Deep sea drilling efforts considered to date could encounter a wide spectrum of unanticipated problems. For example, site selection will be based on minimizing the likelihood of encountering pressurized hydrocarbon formations. However, the drilling system must be fully capable of dealing with such an occurrence with complete safety since geophysical data are not completely reliable.

A basic casing program (i.e. , a series of various lengths of different diameter tubes), wellhead, blowout preventer, and riser will have to be selected. Deep penetration and the anticipation of numerous well-control problems plus the constraint of a minimum core diameter all suggest a large-diameter riser/blowout preventer system. On the other hand, a larger riser is heavy and bulky to handle and incurs great horizontal forces from the current and waves. These must be compensated for by the ship and the wellhead.

Deepwater drillships now use 16-3/4″ diameter blowout preventers and associated riser and wellhead systems. This arrangement permits a maximum of 4 casing strings to be run through the riser starting with a 13-3/8″ diameter. In the ocean margins drilling program, the **30″ and 20″ strings have to be run without the protection of a blowout preventer; this is currently standard offshore operating procedure. The Glomar Explorer may**

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allow for storing and handling an 18-3/4″ riser, which would permit running an additional casing string through the riser. Use of the larger riser, however, would most likely involve a more elaborate wellhead system to support the heavier stack and greater loads from the riser.

Drilling for Surface (Structural) Casings

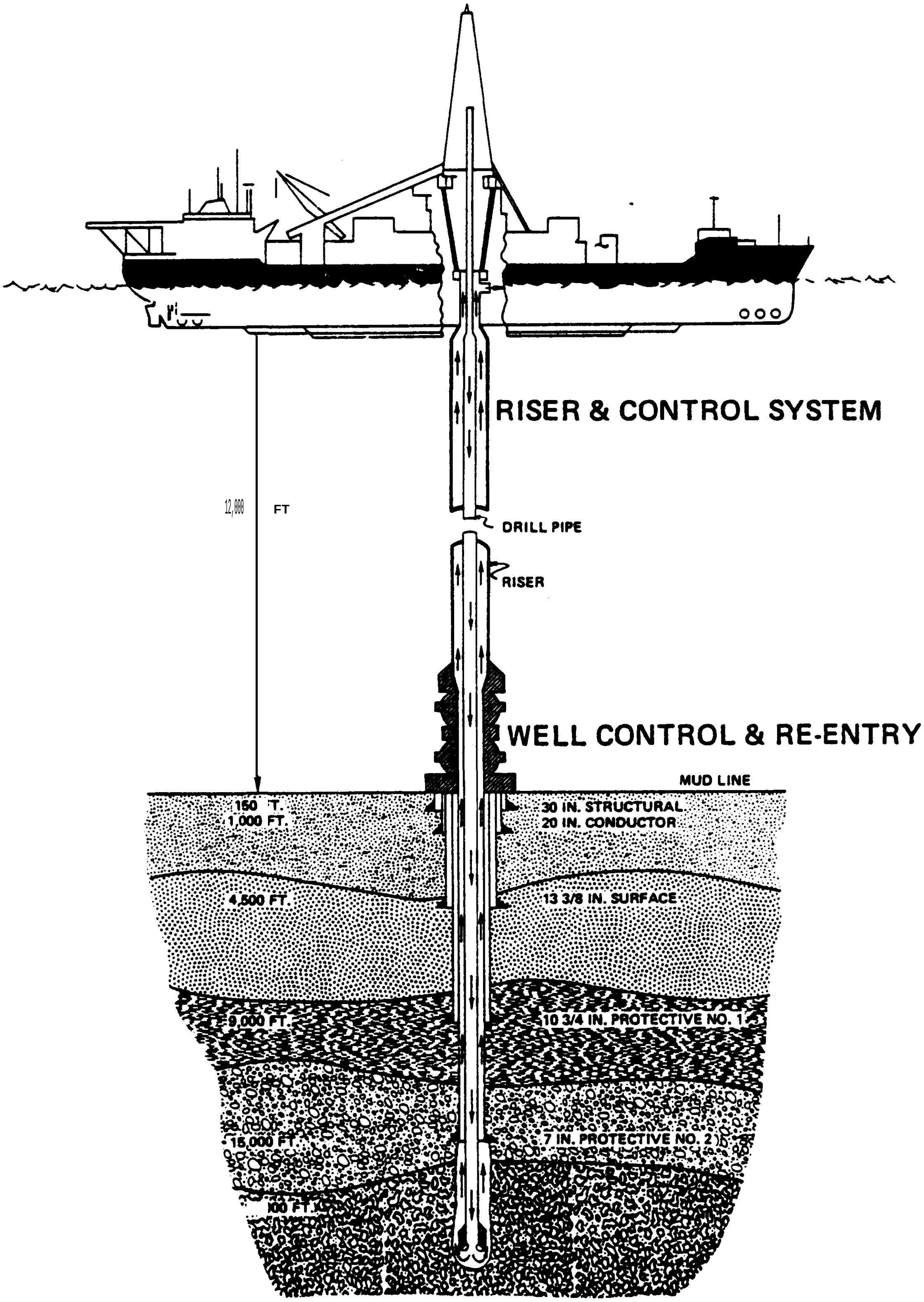
In deep water, drilling with a 30″ or a 20″ casing (and a 16″ casing if it is used) is often done without a riser. Prior to setting a 30″ casing, the riser has no foundation and the casing is usually not sufficiently founded to support the riser loads alone. A small pilot hole is usually drilled prior to drilling to emplace these large casings to determine if shallow gas or other geological hazards are present.

Nonetheless, in U.S. continental shelf waters and those of some other countries, regulations require running the riser for all drilling operations after the largest surface casing is set. In 13,000 feet (approximately 4 km) of water, it will probably be almost impossible to set a 30″ casing capable of supporting the riser loads. Should this occur, the riser may have to be mounted on a pile-founded support on the seafloor, a problem with no precedent in these water depths.

A packer or downhole blowout preventer in the drillstring can also be used to protect against shallow gas during drilling. Should shallow gas be encountered while drilling without a riser, the packer can be inflated to shut off the flow. A heavy “kill” fluid or “mud” mixture can then be

Figure 2

Diagram of a Typical Deep Water Riser Drilling System



Source: Project Contributions Program Review for Director NSF Presented April 3, 1978. Deep Sea Drilling Project IPOD.

circulated behind the packer to set the casing or to cement and abandon the hole. Some development work has been done on such a device, but it is not nearly to a state of field readiness.

Another problem associated with surface casings is that they are too large to go through the riser. If the riser is run for the drilling operation, it must be pulled while the casing is run into the hole. In 13,000 feet of water, this is a time-consuming and expensive procedure. An attractive but untried technique would be to set the riser aside; i.e. , have a means of physically moving the riser off to one side, support it there, and running the casing into the hole without bringing the riser onboard the ship.

Riser Handling (See Figure 2)

Handling the riser correctly becomes critical in extreme water depths. For example, deploying and retrieving the riser -- usually a simple procedure -- may be extremely difficult if there is even a mild current over most of the depth. As the riser is deployed deeper and its sail area increases, it tends to get pushed to the side by the currents.

The requirement for a thorough understanding of environmental conditions that may impinge on design and handling of the riser can be supported by several operational scenarios. An example is the almost imperceptible, long-period swells to be expected in some areas, such as extreme southern latitudes, where major and unpredictable axial loading of the riser can result. Adequate advanced surveys, predictive capability, and monitoring while operating will alleviate such potential problems.

As currently designed, deepwater risers are nearly neutrally buoyant. If a buoyant riser is used, a variable buoyancy system will probably be necessary to make the riser less than neutrally buoyant as it is being run and so that it can be lightened after it is connected at the wellhead. On the other hand, the Glomar Explorer can support a non-buoyant riser. This is an extremely attractive possibility for the ocean margins drilling program.

Moving the vessel away from the wellhead also presents problems. In the event of a severe storm, the ship's safety would be jeopardized if it had to maneuver with a 13,000-foot riser hung from the moonpool. Generally, there will not be enough time to pull the entire riser up and store it aboard the ship. Thus, even with a buoyant riser, an upper disconnect platform may be needed several hundred feet below the surface. The riser could be disconnected at this point, with the remainder becoming positively buoyant.

This approach has been considered before, but has not yet become operational. Much needs to be done to provide high reliability in the re-connection process. Two important components -- an underwater electrical connector and controllable buoyancy -- are being developed by the petroleum industry, but are not fully operational.

In drilling into the earth, a drilling fluid (often termed “mud”) is circulated down the drillstring and back up the annulus between the drillstring and the drilled hole. The mud cools and lubricates the drill bit, prevents formation fluids from entering the hole by controlling the pressure at the bottom to keep the hole from collapsing, and carries the formation cuttings made by the drill up to the surface. The bottom-hole pressure is controlled by variations in either the mud weight (usually expressed in pounds per gallon), the pressure applied by the mud pump on the surface, or both.

The mud pressure at the bottom of the hole must be:

- Greater than the hydrostatic and formation pressures to prevent formation fluids from flowing into the hole; and
- Enough greater than the hydrostatic pressure to provide sufficient velocity of flow back up the annulus to carry the cuttings to the surface; but
- Less than the fracture pressure to prevent “lost returns,” where the mud breaks up the formation and flows into it rather than back up the annulus.

A “gas kick” occurs when the drill enters a portion of the formation where appreciable geopressure exists (e.g., because of the presence of gas). When this occurs, the mud weight or pressure must be changed rapidly and

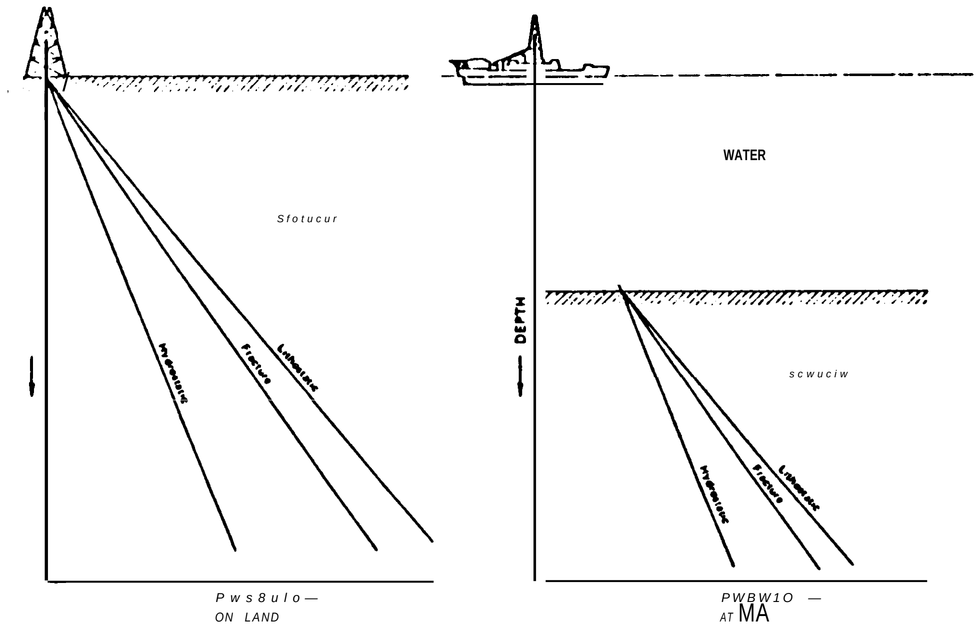
accurately to withstand the sudden increase in pressure and prevent a blowout or uncontrolled flow out of the formation and up the hole.

Herein lies the basis for some of the major problems with deepwater drilling. When drilling on land (see Figure 3), the hydrostatic and lithostatic pressures increase simultaneously from the same starting point. The difference between these two pressures continually increases. This provides room to work between the two pressures in controlling well pressure and potential blowouts.

In deep water, however, the lithostatic pressure begins to increase at the ocean floor where an appreciable hydrostatic pressure already exists. Therefore, the hole must be lined with a structural shell or casing for some depth to provide a “spread” between the hydrostatic and lithostatic pressures. This allows the mud or some other drilling fluid to be used to control lost returns and blowouts. Further, the deeper the water the greater will be the length of structural casing required to provide “working room” between the hydrostatic and lithostatic pressures. The structural casing is also required to provide foundation to support the wellhead, blowout preventer, and riser base.

A widely accepted basic rule of drilling safety is that the drilling mud is the first line of defense against a kick or sudden flow of gas or formation fluid into the hole. In very deep water, much of the mud column required to maintain control is in the riser. If the riser must be disconnected, part of the downhole pressure is lost. In some cases, the mud remaining in the hole is insufficient to prevent a potential kick with

Figure 3



GENERAL RELATIONSHIPS AMONG PRESSURES THAT ARE RELEVANT TO DRILLING AND WELL CONTROL

Source: Marine Board, National Research Council, "Engineering for Deep Sea Drilling for Scientific purposes." National Academy of Sciences April 1980, p. 27

systems now in use. Closing the blowout preventers would provide the extra protection required.

With the deepwater system envisioned, the extra protection may eventually be provided by one or more of the following items:

- Downhole instrumentation to provide more immediate surface warning of undue pressure increases, coupled with a pause in drilling to provide time for more precise adjustment of mud weight.

- Deeper or more frequent casing settings.

- A secondary downhole blowout preventer or inflatable packer run in the drillstring that could be activated to seal the hole near the bit.

Because these systems may need modification to adapt them to deepwater use, there is a need for intensive engineering evaluation and testing. Also, the probable greater dependence on the blowout preventer in the well-control system emphasizes the need to ensure blowout preventer/control system reliability. The greatly increased cost of pulling the blowout preventer up to the ship for servicing during long drilling operations is sufficient incentive to improve reliability.

Circulation of Gas Kick

The conventional method of circulating a gas kick is to bypass the riser using the choke or kill line (a small-diameter line located adjacent to the riser) to direct the gas flow to a controlling choke (valve) at the surface. In very deep water, this method is difficult and time consuming because of time lag in the flow through the small diameter line. A constant downhole pressure must be maintained as the gas comes up this small-diameter line instead of the riser; this is often difficult to do. An alternative technique involves a seafloor choke that controls the gas flow at the wellhead. A prototype choke has been developed, but has never been field tested.

Drilling and Well-Control Simulators

Computer-based simulators can help prevent blowouts, control wells, and circulate the gas kick. Computer simulations can help to check out equipment concepts and operational procedures prior to design completion. Although sometimes considered to be simply training aids, they also permit early qualification testing of instruments, control station layouts, and many items of equipment

Reentry and Seafloor Manipulation

Many drilling rig operations use a manned submersible to land the blowout preventer, to land the riser on the blowout preventer, and to do routine operations and maintenance essential to continued drilling. Other rigs depend entirely on remote reentry systems and on manipulating devices that can be handled on the end of a drillstring and watched with a remote television camera.

The decision whether or not to use a submersible in the NSF program will affect program time and cost. No manned or remote controlled submersible now being used by industry can dive to more than half the depth called for by the NSF drilling program. The one exception is the Alvin, a deep-diving research submersible.

The development of a submersible could cost $10 million to $20 million and take 3 to 4 years to build and test. Operating without it, however, might be extremely costly should seafloor problems cause the loss of a well after many months of drilling. This decision will probably be based on an extensive examination of the operating experience of deep-water rigs.

Blowout Preventer Pressure Integrity and Wellhead Structure

Greater water depths lead to higher hydrodynamic lateral loads on the riser, simply due to its greater profile area. Furthermore, the blowout preventer will probably be taller than those now used, which extend more than 40 feet above the seafloor. Because of this height, the blowout preventer, wellhead connector, and wellhead structure could become bent at times. Higher bending moments will substantially reduce the ability of the clamps that tie the segments of the blowout preventer together to withstand pressure. These clamps are already marginal at present deepwater conditions, and will have to be strengthened. Wellhead connectors will also require upgrading.

A careful check of the wellhead structure strength will have to be performed at each new site. It will depend on soil measurements at each site. The high bending moments that must be tolerated will likely require wellhead structures larger than those now used to distribute the load over a broader area. These checks should be made early because of the time needed to design and build special wellhead structures.

VI. Industry Participation in the Program

The potential of oil and gas resources in the continental margins is subject to much speculation, but competent geologists claim that these areas hold significant promise at least to the extent that they should be carefully explored. The ocean margin drilling program would help establish better scientific information on which to base further speculation on hydrocarbon resources, but as designed it falls far short of a logical program to explore for oil and gas. Some petroleum companies claim that they are not participating because it is not directed more toward assessing commercial resources. Others claim that they are participating because they expect the scientific benefits to help them in the long run. The U.S. Geological Survey expects to benefit in their efforts to evaluate long range oil and gas potential in offshore regions.

Eight petroleum company participants will decide whether they will help fund first year efforts in July 1980. Most of these participants are supporting the program because they believe it will produce valuable basic science and have some secondary benefit to their interest in possible future oil and gas resources in the ocean.

OTA contacted representatives of the petroleum company participants and some additional companies who declined to participate in the NSF program. In these discussions, many companies expressed their concern about their liability as participants in the program if they have no management control over the operations. Several companies are also concerned about the level of funding required by each and believe that more companies need to be involved to assure the program's future viability.

While technology for very deep drilling is considered by all of the petroleum company participants to need significant development, some are concerned that either the cost estimates are too low or that the chances of reaching all the deep holes are not good. It appears, in general, that industry participants will force future decisions on realistic technology development goals and cost estimates.

Industry support for the ocean margin drilling program is tempered by the above factors. One reason for this is that only 5 of a hoped for 20 companies are actively participating as of May 1980. NSF hopes that a total of 8 will be participating by July. This does not place a severe financial burden on those companies during the first year. Many feel, however, that greater participation is needed in subsequent years when a much higher level of funding is necessary.

Closely connected with some apprehension by industry participants is the manner in which most companies evaluate the benefits of the program. In general, the funds which each of the companies would commit are not "new" funds but would be reprogrammed from present industry research and development budgets. Thus, some are concerned about giving up some company research and exploration in exchange for participation in the NSF program. Some non-participating companies are keeping close watch over the program and, if the program benefits change, they may decide to join.

Benefits to Industry

The companies that OTA surveyed expressed a variety of reasons for participating. Some that do not have extensive technology development programs themselves, felt that will be the principal benefit. Riser technology and well control were two specific areas mentioned. None of the companies felt that information on potential commercial resources would be a great benefit.

However, some foresaw benefits related to the science of sedimentary geology. Very few felt that there were specific, substantial benefits to industry. However, they felt that there would be long term intangible benefits, similar to those from the deep sea drilling program, and from new ideas that are derived from the results.

Perceptions of Industry as to the Science and Technology Quality of the Program

With respect to industry views on the scientific merits of NSF's ocean margin drilling program, several industrial members stated: 1) it will fill gaps in knowledge, 2) good scientific talent is on it and thus the program must be good, and 3) it will result in a scientific enrichment similar to that achieved earlier by the deep sea drilling program.

Other industry views in questioning the program include:

1) **"Too little attention is being given to initial survey work and to reflection seismology."**

2) **"It is good science, but whether it is an effective use of the money to get the information is debatable."**

3) "The science is being developed backwards. the scientists are narrowing themselves down to one option too soon. They need to develop better regional data."

4) "The program is unfocused and has too much of the attitude of let's drill and see what we find out; the deep sea drilling program was much better focused on specific scientific questions."

Several industry participants expect the program to advance riser technology, well control, and metallurgy. They feel they have the technology in hand to drill in 6,000 feet of water and that the capability increases at about 600 feet per year. This program could provide technology to drill in 13,000 feet of water, which oil and gas companies would not otherwise pursue in the near future. Also, industry involvement is considered important for advancing the technology in this program.

Increase in Resource Potential Knowledge

Most industry participants agree that the program will not generate significant assessment of commercial resources, but only bits of boundary information from which some inferences might be drawn.

Other comments from industry included:

1) "Resource knowledge would be gained in an indirect way. New ideas may be generated with respect to source rocks or settings that might be conducive to production. However, the program

would not provide the information necessary to define any reservoir."

2) **"The program can result in a better geological picture of sediments and thus aid in the analysis of basins."**

3) "We expect to gain knowledge concerning sediments in the areas being studied and will be able to draw some conclusions regarding specific areas of opportunity."

4) **"As for improving the knowledge of oil reserves, the ocean margin drilling program would not be the way to go about it."**

Additionally, several petroleum companies are concerned that government leasing decisions might be made as a result of the small amount of information gained in the ocean margin drilling program. However, a much larger data base would be desirable than will result from this program.

Problems Identified by Industry

Industry participants believe that program costs may escalate due to unrealistic goals set by some scientists. They think that compromises will be necessary between science and technology in the future, particularly with regard to very deep riser drilling.

To satisfy scientific goals, there will be difficulties in developing satisfactory instrumentation for well logging, according to some industry representatives. Also, the drilling system will have to address some major problems, including riser development and the adequacy of metallurgical materials used to drill where high temperatures will be encountered.

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There is also concern as to the adequacy of the technology for controlling wells and the on-site management of drilling operations. Drilling at sites where there is no backup to kill a blowout is particularly disconcerting. If the Glomar Explorer is the only ship capable of deep water drilling with a riser and a blowout preventing system, no other vessel could be engaged to kill a blowout if one occurred.

Some participating companies question their liability in case of a blowout. Parallel to that is a concern about antitrust considerations. Presumably, geological data and information on new technology will be published. Non-participants might ask whether it is published in a timely fashion with respect to any leasing on adjacent tracts.

The resolution of these various problems will be required for industrial participation in the drilling program as will the determination of technical feasibility and accurate cost estimates.

Alternative Suggestions

Some industry representatives surveyed by OTA suggested alternative approaches to the program. In general, these emphasized the need for academic scientists to undertake a large seismic program prior to defining a drilling program and then to consider alternatives such as using available drill ships instead of refitting the Glomar Explorer for drilling the holes in shallower water depths. One specific suggestion for the technology development was to outfit the Glomar Explorer only for setting deep risers and not convert it to a drilling ship. It could then be possible to use any of a number of available commercial platforms for the drilling operation.

Some other alternatives suggested were:

1. Undertake the research in conjunction with industry's normal progression of technological development using available ships as required. A large part of the slopes can be evaluated with present riser technology. Conduct the deeper drilling later.

20 Keep the Glomar Challenger program active for several more years. There are significant benefits to be derived from additional holes along the edges of the sediment slopes.

3. Provide academic scientists with advanced geophysical equipment (arrays and processes) and a ship for work in research related to sediment stratigraphy and crustal formations. Undertake a significant seismology program before undertaking the ocean margin drilling program.

4. Undertake a drilling program on the continental slopes of North America using available technology and, simultaneously, undertake a worldwide, multi-phase seismic survey. Follow this with a deep drilling program in prospective areas defined by the seismic surveys.

One industry scientist asked whether it is actually necessary to go to a 13,000-foot water depth to gain the required scientific information. He also asked whether sites around the world could be found at lesser depths that would still represent critical geological formations of interest.

Industry recognizes that geophysical seismic reflection work has to be followed up by drilling, which is the only way to gain some of the most significant information. However, some industry members said that NSF's program did not reflect the need of scientists to review priorities in margin geology during its first year.

Program Costs

Industry's view of the accuracy of projected costs varies. Some feel that the costs allocated for ship modifications are low and that it would be less costly to build a different ship. Others say that until the first phase studies are over, it is not possible to project costs with any accuracy. Still others conclude that they are getting good estimates. Since the costs are based on specific holes and drilling time allowed (not required) they are probably about right.

Cost estimates are an important output of the program's first phase and will be of extreme importance to both government and industry.

Funding Reduction with Program Extension

In general, most of the industrial participants feel that a funding reduction and program time extension would be beneficial and probably more realistic. Some believe that the technology will take longer to develop than scheduled. From a scientific point of view, some felt that extending the program by delaying the drilling phase would result in a better definition of both the program and the modifications required to the Glomar Explorer. It could also allow NSF to select another drill ship.

One industry scientist particularly felt that reduced funding and a stretched out program would be excellent in that it would enable a proper program progression. Academic scientists could gain greater capability through acquiring advanced seismological equipment, could conduct the necessary reflection seismology, and thus could make a more judicious selection of the sites to be drilled (the main program cost).

VII. Program Management Considerations

The National Science Foundation has successfully directed the deep sea drilling program over the past 10 years using oceanographic institutions to manage the scientific effort. The ocean margin drilling program is a major increase in money and complexity from previous efforts and thus the capability and appropriateness of NSF to manage it is subject to question. Several problems have been noted and should be considered. These include: whether NSF can effectively manage the considerable technology development work, whether extra funds that could be needed for technology would be taken from other programs, whether the possibility of finding oil and gas resources should bring DOE or USGS into more direct involvement, and whether the science is overshadowed by the technology.

The ocean margin drilling program is similar to the deep sea drilling project and other programs NSF has directed. Similarities include operating a drill ship, a drilling operation, site selection, and site surveys. Management experience gained from earlier projects will be particularly helpful in developing a management structure at NSF for the ocean margin drilling program.

The proposed management structure for the program relies on the current staff for the deep sea drilling project, a systems support contractor, science support contracts with JOI Inc. , and a future systems integration contractor. As in the deep sea drilling project, JOI Inc. is scheduled to organize a number of panels, which will provide the scientific direction for the program. 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.

In addition to the basic program management, NSF plans to establish outside groups to advise both the director and the ocean drilling program team. A program advisory committee will comprise 40 percent industry representatives, 40 percent from academia, and 20 percent 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 their 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 used as required to assist various facets of the program as it develops.

In managing the program, the three major aspects are operational scientific, and technology development. Scientists are concerned because of the current emphasis on the operational and technology development aspects. The plan developed in March 1980 has not yet won wide support from the basic research community. This may be because there has not been enough time for everyone to become familiar with it. Or it may result from the fact that earlier expectations can not be met within the financial, time, and engineering constraints faced by the project. A more detailed, overall management plan for science, such as spelling out the responsibilities and authority of NSF, industry, JOI, Inc., and the panels, may answer some concerns.

Since the 1977 FUSOD meeting in Woods Hole, planners and participating scientists have stressed the need for extensive geological and geophysical studies as a prerequisite to site selection and drilling. This is called problem definition and goes beyond the specific site surveys that will be needed before drilling begins. The fact that tentative sites were identified at Houston in March 1980 does not negate the need for problem definition.

For example, OTA'S panel suggested that the tentative drilling site on the eastern U.S. continental margin may not be the best place to drill to obtain maximum scientific advances. Several years of intense geological and geophysical research are still required before the regional setting for the drill site will be adequately understood. The planning process for this effort has just begun.

The funds identified for science in the Houston plan are listed under "scientific program (survey)." We must assume that these funds are not only for site surveys but also are for problem definition, scientific participation in the drilling phase, interpretation of logging, etc. If SO, it would be reassuring to the scientific community to have a detailed breakdown and plans for use. Another point that needs to be addressed in science funding is the program for the routine analysis and scientific studies of core samples once they are in core laboratories. No allowance was made for this research in the deepsea drilling program. Careful consideration should be given to this issue now.

The site surveys will require equipment that is not now available on academic research vessels, like narrow beam echo sounding. Many institutions are planning to use academic research ships for site surveys. If that is the case, the NSF Office for Oceanographic Facilities and

Support and university ships coordinating groups should be brought into the planning at the earliest possible stage. Another possibility, however, is to charter ships from industry. This may appear more cost effective, but its impact on the academic fleet could be severe.

The possibility that operational funds will have higher priority than scientific funds during the program concerns many scientists. Some means is required for assuring that funds for science will be protected against the overwhelming demands of logistics and operations. Although some safeguards are built into the ocean margin drilling program, such as industry agreement to share overruns and funds from international participation, more adequate arrangements are needed. NSF could consider assigning administration of science dollars to one of the other divisions. Both earth sciences and ocean science would be suitable. Adoption of this procedure would assure strong guardianship of the science funds as well as good scientific overview and administration within NSF without having to hire additional science administrators.

Another major concern of scientists is that, because of the very large budget for ocean margin drilling, the budgets for all other earth and ocean sciences programs within NSF will suffer. This is a real possibility despite the fact that the ocean margin drilling budget is an add-on to NSF's present budget and the petroleum companies are providing half the funds.

Unforseen cost increases in later years will probably affect the internal budgeting of NSF's earth and ocean sciences rather than any other part of the Foundation. NSF will need to make a special effort to avoid such a negative impact on the other earth and ocean science programs. And

Congress may wish to keep this problem in mind in its annual review of the NSF budget.

Also, because of its size and the involvement of such a large segment of the geology and geophysics community, the ocean margin drilling program might skew the field sufficiently that it would impede progress in other areas of geology and geophysics. In a similar vein, ocean margin drilling might skew NSF's science management at the administration and division levels to the point where other earth and oceans programs might be neglected.

NSF is currently preparing an environmental impact assessment of its program, including possible impacts of riser and riserless drilling. The importance of science and resource evaluation are the rationale cited for performing the program. The assessment covers alternatives to the program ranging from abandoning it because the anticipated impacts are too severe, to limiting the drilling depth.

Because the program's impacts on the "oceans" cannot be determined, a generic statement will be issued and yearly environmental impact statements will be released after each new site is chosen. The supplemental statement will be based on geophysical surveys and samplings performed at each drill site. Impacts or possible environmental consequences of the program that have been identified and will be studied include possible changes in air and water quality, disposal of cuttings, and possible oil and gas "accidents."

Other government agencies, including USGS and the Coast Guard, and environmental groups have been contacted and their suggestions incorporated into the assessments.

Regarding the appropriateness of NSF to manage the ocean margin drilling program, several factors suggest that it should be the lead agency. These are:

- Efficient and successful experience with the scientific, engineering and operational aspects of the deep sea drilling project and the Glomar Challenger.

- Basic research aspects of ocean margin drilling dovetail with NSF'S mission and will benefit from its other scientific programs.

- The basic research orientation of the program will probably continue to be emphasized.

- NSF has the respect of scientists and other government agencies for handling basic research. It may be the only agency acceptable to all parties for handling this kind of program.

- NSF' may be the most stable agency, with regard to its mission and orientation, for the life of the program.

- Ocean margin drilling would be a major program of NSF and would have the continued attention of the agency.

There are also several factors that suggest another agency lead and or support from other agencies like DOE or USGS. These are:

- o The National Science Board appears to have a slight bias against big science. The administration is more comfortable with small science programs.
- o NSF has had little experience with joint industry-academic programs.
- 0 NSF is still a relatively small agency and may get caught in a squeeze between industry, the Department of Energy, and the Department of the Interior.
- 0 If the program objectives change from basic research, NSF may not be the appropriate agency.
- 0 The large amount of technology development in the program may be difficult for NSF to manage.
- o Assessing resources is not part of the NSF charter.

In conclusion, the details of the overall management plan for science, like the responsibilities and authorities of NSF, industry, JOI Inc. and the panels, are not yet well spelled out. Furthermore, neither the new ocean margin drilling division nor the JOI Inc. staff yet appear to have sufficient scientific or technical strength for proper management of the scientific aspects of ocean margin drilling.

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Letter from John Sclater to Congressman George Brown, Ca., February 24, 1980.

APPENDIX A

Alternatives To The Ocean Margin Drilling Program

Suggested by

OTA Panel Members

Dr. Joseph R. Curray

Dr. Charles L. Drake

Dr. James D. Hays

Dr. John Imbrie

Dr. John G. Sclater

Dr. Tj. H. Van Andel

Alternative Suggested by

Dr. Joseph R. Curray

Scripps Institution of Oceanography

Extension of the program schedule appears to be already occurring, and I consider it a good thing. My personal and scientific preference would be for some additional delays in the conversion of Glomar Explorer and development of a riser capability, with the intervening years to be filled in by continued Glomar Challenger drilling, utilizing the exciting capabilities of the hydraulic piston corer. In addition, during these intervening years, extensive geophysical work should be funded on continental margins and in other prospective drilling areas.

Glomar Challenger **cannot continue indefinitely. The ship apparently** has a finite remaining **economical life.** A few more years of operating with the hydraulic piston corer, however, would be strongly supported by the scientific community but I certainly do not advocate eliminating the OMD Program.

In summary, I advocate a slightly modified program, as outlined briefly above: some delays in development of Glomar Explorer capability, with funding of additional Challenger HPC work and extensive geophysical surveying, both on continental margins and in other parts of the world. Ideally, this alternative program would simply delay the major part of the OMD Program, but would provide time for additional utilization of HPC for stratigraphic and climatological purposes and for much more extensive geophysical surveying. The stratigraphic and climatological objectives with HPC are important, but in my mind are no more important or of higher priority than the deep-drilling objectives of OMD. Instead, they represent an attempt at refinement and an opportunity to gain more data points in the shallow part of the section; whereas OMD offers the first-ever opportunity for deep drilling, both deepwater and deep-penetration, on continental slopes and rises.

There is a great deal of concern in the marine geological community that will preclude optimal utilization of HPC. The alternative program described briefly is a compromise, trading increased support of HPC geophysics for delay in timing of OMD.

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Alternatives Suggested by

Dr. Charles L. Drake

Dartmouth College

Alternative Scenarios

There are a number of alternative scenarios that could be suggested, some productive, many destructive. In any of these it should be recognized that no one is against the fact of drilling, for drilling provides the moment of truth - the hard data that confirms or denies the geophysical interpretations. There may well be, on the other hand, differences of opinion on methodology, on timing, on focus, and on how the costs should be borne.

a. We might start with the Luddite approach, eliminate the drilling because of its very high cost compared to other options. The emotions behind this approach are real and stong, but they presume that the funds exist for application to other purposes. In the no bottom line budgeting process this is not really true. If there is a real limit to the budget of NSF, it may be true. This alternative cannot be appraised realistically unless one knows whether there are trade offs and what they are.

b. The Hedberg approach suggests that industry play a more important -even a major- role. This is an appealing option, but there is no free lunch. I doubt whether the Congress is prepared at this time to lease the large tracts that industry would need to justify the major investment. I would also have some qualms, were I in industry, about how far I could go with cooperative ventures of this sort before there were the anti-trust problems.

co The present program is an NSF program with NSF as the prime agency for footing the bill. The rationale is that it is a science program and NSF is the primary science support agency. This could be argued. The present program is at least as much a technology program as a science program, and many of the industry people hint that they are looking for appreciable technological fallout from it. The limitation to water depths greater than 2,000 meters supports this suggestion.

Industry probably would not move into riser drilling at abyssal depths for a decade or so. What a splendid opportunity OMD presents for letting someone else pick up the tabs for mistakes. This should not be construed as an argument against drilling, but might well be taken as an agrument for DOE participating in the funding. DOE is throwing all sorts of money at other technologies. One also has the gnawing feeling that the relevance of OMD to specific USGS missions ought to create more enthusiasm for funding from this source than has been obvious to date.

d. Many of the scientific objectives in the continental margins could be reached by drilling vessels in existence or nearly so. If the whole drilling program spelled out by FUSOD were to be carried out, obviously it would be necessary to have a vessel with the capability of drilling in abyssal depths. If the focus is on the continental margins, and ocean crust and paleoenvironment can be shoved under the

rug, perhaps some reappraisal is in order. I submit , and Bally has submitted in some of his statements, that proper geophysical and geological investigations can locate drilling sites on the continental margins that are responsive to the scientific questions and that could be drilled using existing vessels. The scientific rationale for the Glomar Explorer weakens markedly as the emphasis on the continental margins grows stronger. If this approach were followed, to drill with leased vessels on the margins, then the possibility of continuing the Glomar Challenger or a suitable replacement to carry on abyssal drilling should be examined carefully.

e. The HOUSOD report provides a few crumbs for all, but satisfies no one. Perhaps it would be more productive to bite the bullet and concentrate efforts in one area, such as the East Coast or the Gulf Coast. This concentration would keep the vessel near good logistic ports would minimize drilling time lost in steaming from one location to another, and would greatly increase the chances of solving the problems in that area. If this alternative were followed, it would again be desirable to remove the 2,000 meter restriction and to drill in the place with the greatest promise of providing answers to the scientific questions. Again, this would abandon abyssal drilling and the question of continuing Glomar Challenger type drilling should be reexamined.

f. Finally, it seems to me that the crux of the problem is whether this is a science program or a technology program. If it is the latter, then I do not think that it should be financed by the National

Science Foundation. If it is the former, then the focus should be on how to do best science in the best place with the best available technology. If it is a mix, as it is reputed to be, let us be sure we are doing the science with the best technology and that the costs are equitable borned by those institutions which have, or should have, a stake in the game.

Alternatives Suggested by

Dr. James D. Hays

Lamont-Doherty Geological Observatory

Alternatives to the Program

The most appealing alternative to the present program, one that could address exciting first order scientific problems, stimulate the broad interest of the scientific community and not cost the taxpayer much more than the present deep sea drilling program would be a program that had two major thrusts. The first would involve a continuation of the present Glomar Challenger drilling program, the second a Continental margin geophysical survey program.

Continuation of Glomar Challenger Drilling

During the last two years a major technological advance has occurred in the recovery of soft sediments from the ocean floor. A hydraulically driven piston coring device (the Hydraulic Piston Corer, HPC) has successfully recovered hundreds of meters of undisturbed sediment and has proven that it is possible to obtain continuous sequences of this length. This device opens the way to a whole series of exciting studies including (1) the evolution of global climate measured on time scales of a decade to millions of years. (2) the evolutionary development of marine plankton during the last 10-15 million years. (3) the sedimentary structure of deep-sea fans deposits which are the most probable reservoirs of any deep-water hydrocarbons. (4) the suitability of various types of deep-sea deposits as repositories for nuclear wastes.

There is no doubt in my mind that these studies plus margin and crustal drilling by a Challenger type vessel would produce far more good science than the OMD program at a fraction of the cost. I'm **also sure these studies would have wide International support.**

<u>Continental Margin Geophysical Program</u>

Continental margins can be studied in a variety of ways. Drilling is only one way and it happens to be the most expensive. So it should be used only after all other means of gathering information have been utilized. It is clear that the more one knows about a margin the more likely one is to make a wise choice in choosing a drill site.

Information about the evolution of Continental Margins can be gained by studying rocks of ancient margins that are now on land. This kind of work should be encouraged. The submerged modern margins can be studied with geophysical techniques and much can be learned from deep-penetration seismic reflection work. I propose that this be the heart of the academic ocean margin program during the next decade (much as proposed in the Bally report). In the meantime Industry will continue to drill wells on the shelves and data from these wells will become part of the public domain. Industry will also continue to develop increased skill for drilling in deeper and deeper water. If in the future after an academic geophysical program and additional Industry shelf drilling, it is judged that there is great scientific merit in a deep-water, deep-penetration scientific drilling program, it will be possible to design it in a thoughtful way. Since deep-water drilling technology will have advanced, it will be far less risky and perhaps cheaper than the proposed OMD program.

I recognize there are other aspects to the program such as resource assessment and technology development. However, these are always billed as bi-products of the scientific effort. I'm not able to judge their value but if they turn out to be the main driving force behind the program then the National Science Foundation should not be the lead agency.

Alternatives Suggested by

Dr. John Imbrie

Brown University

An Alternative Program

A. Setting priorities. What is needed to transform the present, diffuse plan into effective research strategy is an overriding principle that can be used to set scientific priorities. Such a principle emerges naturally from a consideration of the present status of the earth sciences in the context of the national energy crisis. This principle can be expressed as follows: Our first scientific objective should be to understand the structure and history of the continental margin of the United States. Moreover, this research should be conducted in such a way that attention is given first to water depths shallower than 2000 meters -- where the practical prospects for exploiting any reserve that may exist are relatively good -- and then proceed gradually into deeper water where exploitation prospects are now much poorer. As time and resources permit, other scientific objectives should be addressed later in the program.

B. Some guidelines for a restructured program.

1. Geophysical program. The geophysical part of the program should be funded at a higher level and given more prominence than it is in the Houston plan. At all depths, extensive, modern geophysical surveys, conducted by or in collaboration with academic scientists, should precede the planning for the drilling program. Surveys should include both

wide-aperture arrays to explore depths greater than can be reached by the drill, as well as narrow-aperture multi-channel arrays that will provide testable models for the drilling program. Funding of the geophysical program should be administered separately from the drilling program.

2. __**OMD drilling program.**__ **Planning for drilling operations should follow extensive geophysical surveying. Drilling should commence in** waters shallower than 2000 meters, and use existing drilling vessels with **riser capability. Coring should aim at 100 percent coverage.** A decision to **use or not to use the __Glomar Explorer__ for depths greater than** 2000 meters should be deferred until several years into the program, when both the scientific and engineering problems will be better defined. Hopefully, the normal progress of industrial drilling would by that time make the leap to abyssal drilling a less risky enterprise.

3. __Phasing__. The first phase of the OMD program would not be concluded until substantial progress has been made along three East Coast transects. A second phase, involving riser drilling to address scientific problems away from the U.S. continental margins, would then begin.

4. __**Challenger program**__**.** The Challenger-based coring effort **should be continued, at least during** the early years of the OMD program. I **addition to hydraulic piston coring,** this effort might well include crustal drilling and the investigation of non-U.S. continental margins. Research this kind is now planned for __Challenger__ Legs 76-82. As a continuation of the IPOD program, a renewal of financial contributions from foreign countries can be anticipated.

Alternatives Suggested by

by

Dr. John G. Sclater

Massachusetts Institute of Technology

Background

The Challenger Project has been a great success and has had a new lease of life with the hydraulic piston core program and the deep and still open hole drilled about 500 m into ocean crust in the area of the Galapagos spreading center.

I view the OMD drilling program proposed at the Houston meeting as basically a continuation of this Challenger program onto the passive and active margins of the oceans and an attempt to extend crustal drilling to greater depths. This extension of the program to the margins and into thicker accumulations of sediments will require a major advance in technology and have a much greater cost. In view of the technology advancement and the cost it is necessary to re-evaluate carefully the scientific basis of the program.

I think the margins are an important area to study at this time. First, most continents are covered by over two kilometers of sediment and these sediments were deposited by processes analogous to those taking place at the margins today. As we believe we can tackle these margins in a quantitative rather than a qualitative fashion they are an exciting new area of scientific endeavour. Secondly, as there is a possibility of large accumulations of oil and gas any well posed study investigating how these margins were created would improve our chances of finding if and where such accumulations could be found. With the present shortage of oil and natural gas such research is obviously in the national interest.

Clearly eight major oil companies agree with this position. Given that they continue to support 50% of the project I think the science as proposed by the Houston group with certain qualifications worth the cost. As a result of these qualifications I would like to suggest substantial administrative improvements to the project.

1). The Program should be extended over a longer period and start later.

For budgetary reasons this appears to be happening already. However, there are other equally good reasons for slowing it down:

(1) it will enable completion of 2 years of hydraulic piston core drilling on the Challenger and a reentry and completion to maximum depth of the still open ocean crustal hole near the Galapagos spreading center,

(2) it will enable more and better studies to be carried out on the conversion costs of the Explorer, and

(3) it will enable a geophysics program to be developed and partially completed before any of the decisions are made as to where to drill the deepest and most expensive holes.

2). **The program should be restructured and also renamed.**

It is not just an ocean margin drilling program. It is an attempt to apply geophysical and drilling techniques to solve major problems on the ocean margins and in the deep sea. I suggest that to reflect the importance of the geophysics to the program that the $118 million for science be split into two parts.

(1) **$70 million should be separated completely from the present** budget and be given to another program to do the broad based scientific geotraverse work necessary for picking good drilling sites. This project should be given a separate name. Continental Margin Geotraverse (CMG) is an obvious suggestion.

(2) $48 million should be left within the present project to cover site specific geophysical work and other science.

3). The Continental Margin Geotraverse Project

This project allowing for 10% inflation over ten years would cost around $5 million/year at 1980 dollars. It would have a slightly increased budget early in the project when most of the geophysical data was being gathered and a slightly reduced budget at the end when the project was nearing termination.

At present one of the oceanographic institutions (Lament) has proposed to the National Science Foundation and ONR to build and equip a 200 channel, 10 km long, multichannel array for the academic community. This array which is a step beyond the state-of-the-art of industry will enable academic scientists to tackle many problems not soluable with present equipment. The budget estimate is on the order of $9 million dollars. It will cost a further $.5 million to run and $.25 million in processing for each month at sea (costs estimated from Continental Margins Report, page 16, line 10, operating costs $18 million divided by 24 months). Five million dollars a year plus what is already being put into acquiring this data by other branches of NSF and ONR will enable the academic community to run a state-of-the-art multi-channel system for six to eight months each year and do other complementary geophysical surveys (seismic refraction and gravity) in the same area.

Such a program if set up on a national basis (as is the present Challenger program) would be able to tackle the margin geotraverses mentioned by the Continental Margins Report as well as providing the basic geophysics for future drilling. Further it is unlikely that the academic community could handle a larger project than the one I have outlined due to manpower and processing limitations. Thus this project would fulfill much of the goals of the Continental Margins Report (Bally Report).

4)* The Drilling Program

The drilling program should take place after:

(a) the basic geotraverses necessary for adequate site selection have been completed,

(b) the cost wells now available on the slope and some industrial wells that will be released next year have been worked up and

(c) a reasonable and believable estimate of the cost of the Explorer has been worked out.

A rough scenario in my own mind is that, if the project starts in 1981, the multi-channel seismic ship for the geophysical community will take 3 years to complete and 2 years thereafter, in conjunction with other geophysical programs, will have produced the necessary background data for site specific geophysics and drilling. Thus drilling on the shelf or rise would start around 1986 or 1987. I believe this represents a delay of two years to the present program.

5) **Possible political problems with present structure.**

If the project goes ahead it could well founder in the near future because of lack of industry support. With the present structure the whole project would fold.

This does not have to be the case. If my suggestion of splitting the program into two parts (it could be two separate projects or one project with two clearly defined parts) were followed then, if the oil companies pull out and half the money disappears, the project doesn't have to fold. First, the continental margins geotraverse project could continue. It will cost significantly less per year than NSF is now contributing to the budget. Second, what money is left in the NSF budget could be put towards drilling holes in shallow depths with presently available conventional drilling technology. Though this would be a blow to some of the major goals, the program would not be completely wiped out. Personally, I view the geophysical traverses on the margins to be as important scientifically as the actual drill holes themselves. Thus I do not think the loss of the deepest holes should be considered a mortal blow to the project.

Alternatives Suggested by

Dr. Tj. H. van Andel

Stanford University

My program alternatives are as follows:

1. Implement continental margin transect studies and associated programs of the Bally report for the required amount of time.

2. **Strengthen in a major way geophysical capabilities of the oceanographic institutions with truly modern geophysical ships, instrumentation and processing techniques including multibeam echosounding and nearbottom survey instrumentation.**

3. Continue a Glomar Challenger (or similar ship) program of drilling, with heavy emphasis on the HPC. This one, likely to be the ultimate blossoming and reward of the DSDP I would regard as one of the highest priorities in the marine sciences today.

4. Close down DSDP in 2-3 years time with completion of 3).

5* Reassess the need for margin drilling and the state of available technology toward the end of the 1980s when the program under 1 has been completed and digested.

This strikes me as a sensible and properly ordered program taking advantage of the state of the technology, of our present ability to state in operational terms what they key problems are, and logically continuing to take the main trends to where they may lead. All this without extraordinary strain on budgets and other resources. I would like to add that all reference to the resource importance, whether energy or minerals, of the OMD seems to me quite strained. All potential resources are just that, not realities , something perhaps for 20-30 years from now. I do not believe and, apparently, neither do the oil companies, that a real case can be made that the OMD program will significantly advance our access to these resources.

I believe that this approach maintains the momentum created by DSDP at the point where it is greatest (where the questions have been most clearly stated) , that it tackles the continental margin program where the largest return can be found (see Bally report for justifications) and that the total cost is commensurate with priorities of the total national earth sciences program. It is futher a program of manageable size and one that should be comfortably cost-effective. I DO NOT SEE IT AT ALL AS WHOLESALE NEGATION OF The OMD; on the contrary, I believe that it is the essential transitional step and that a responsible OMD is nhot possible without it. I am familiar with the sayers of doom who claim that , once terminated, no marine drilling program will ever by resurrected. I do not believe that that is true; after all, such a program was once erected and that in the face of the Mohole disaster, not actually a very invigorating climate. I believe that insisting on the drilling phase now is equivalent to claiming that continuity is more important than necessity or quality.

The NAE/Marine Board report has questioned the current timetables, and the budget flap we are finding ourselves in is likely to lead to further extension I do not think that extending the time table by a couple of

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years will help a lot , because these extensions will only yield the budgetary relief required by higher than expected costs and larger than anticipated national reductions in the investment in R&D. Consequently, extending the calendar will not do what is necessary, namely to do some other things first, and not begin this costly venture until we are surer of what it is we need to do and have a better (and cheaper) handle on the technology.

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:

- o 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.
- o As long as a ship is headed into the principal swell, it is an acceptably stable drilling platform.
- o 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:

- **to relate the structural evolution, rifting, and early sedimentation to the nature of ocean-continent boundary and to early history of subsidence**
- **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:

- mature margin, e.g., the east coast of the U. S.
- 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

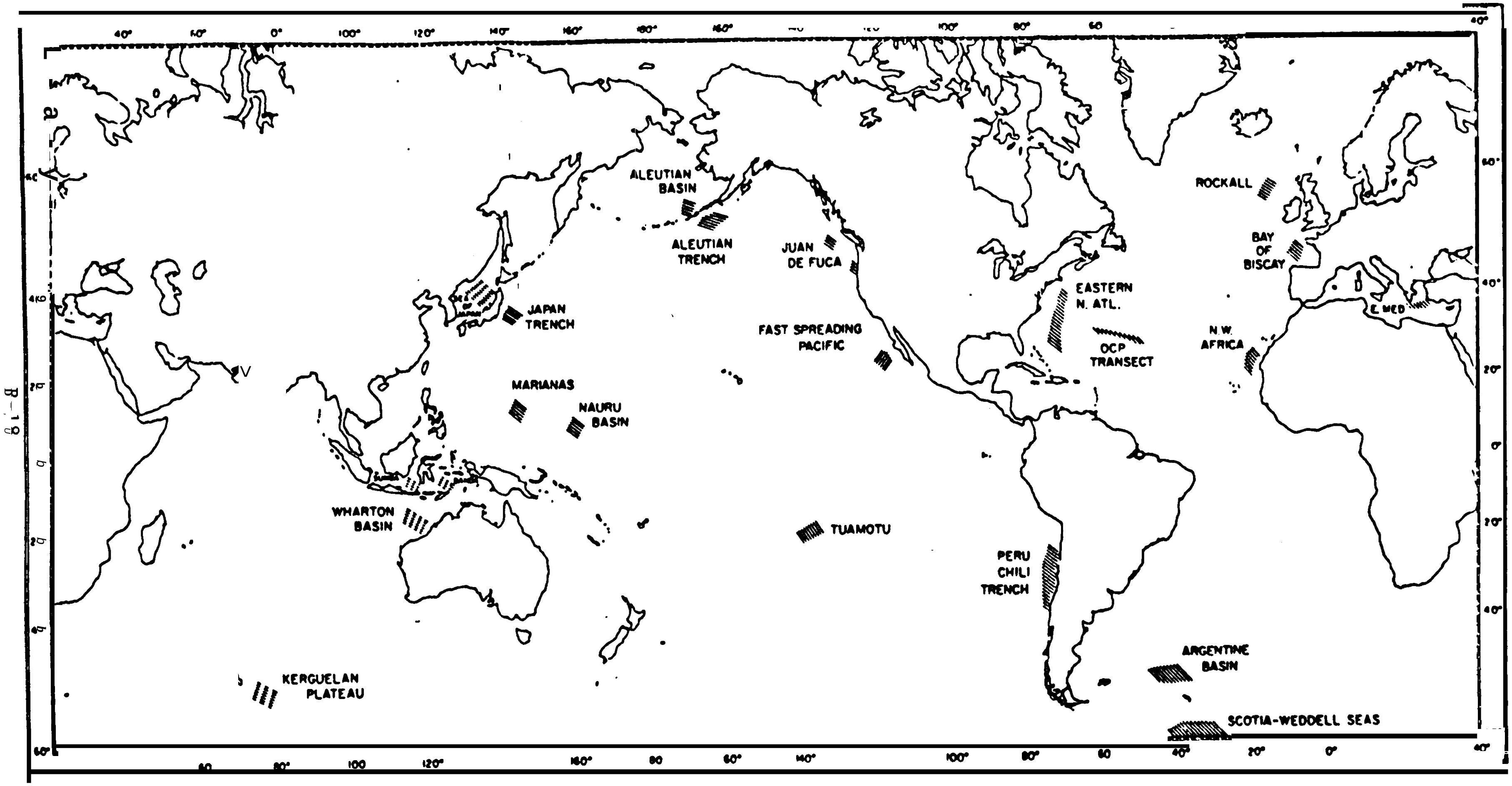
Engineering studies have been conducted during the past several years to determine the vehicle and systems needed to accomplish the drilling tasks and associated work required by the scientific objectives. Although the first of these studies was initiated prior to the establishment by JOIDES of the FUSOD 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

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."

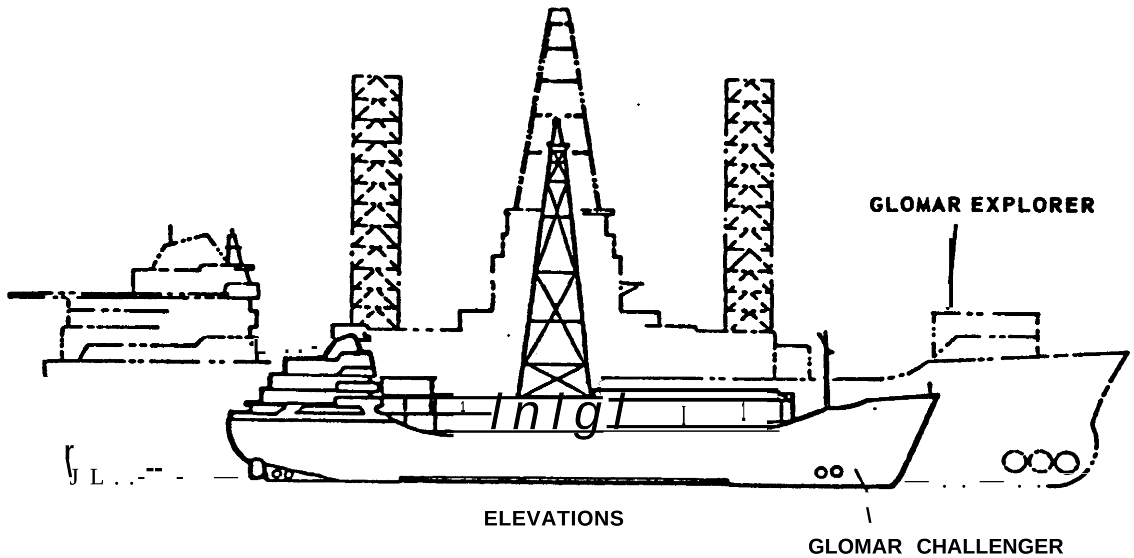
THE GLOBAL MARINE DEVELOPMENT, INC. REPORT

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:

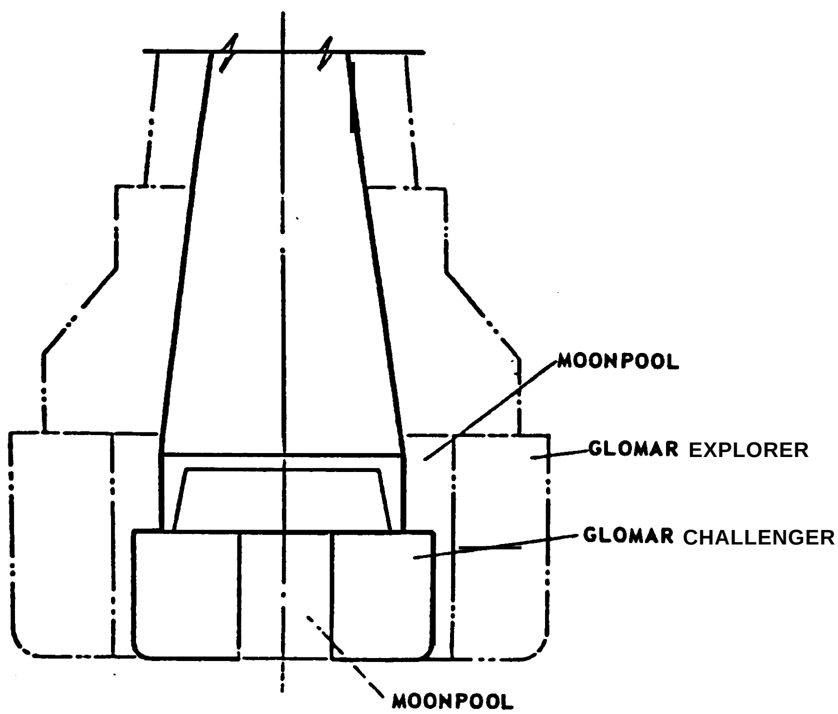
The demonstrated deep ocean performance of the *GLOMAR* EXPLORER, coupled with the present lack of an operational assignment for the vessel, make the U. S. government-owned *GLOMAR EXPLORER* an ideal candidate for the proposed program. GMDI feels especially confident in the feasibility of using this 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:

o 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.

o The GLOMAR EXPLORER, with suitable modifications, appears to be a feasible and financially attractive Ocean Margin Drilling vessel.

o 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.

o 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.

o 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.

o 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 pre-liminary 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 train-ing 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.

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

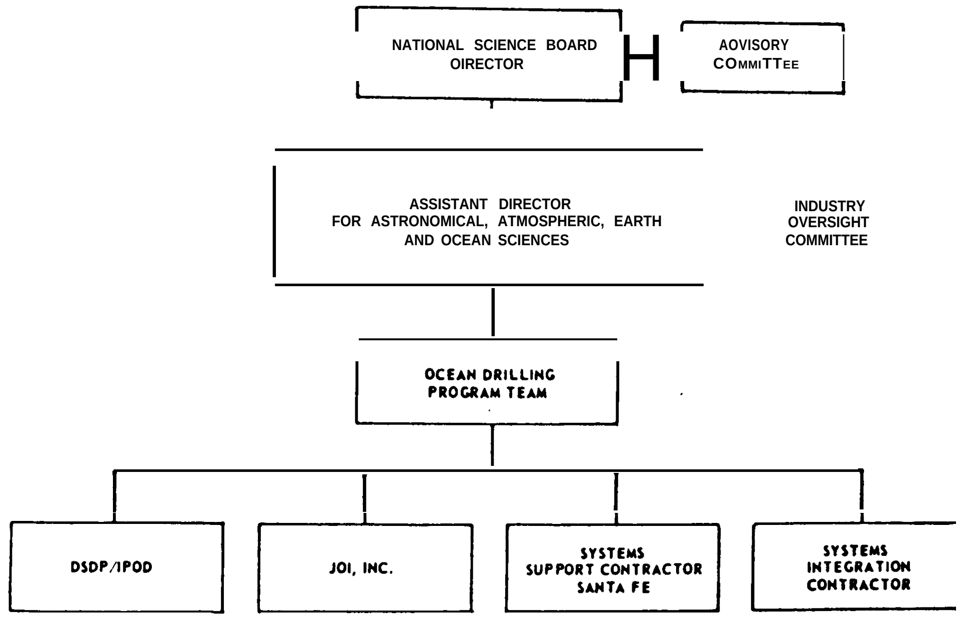
DEVELOPMENT OF A MANAGEMENT STRUCTURE

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.

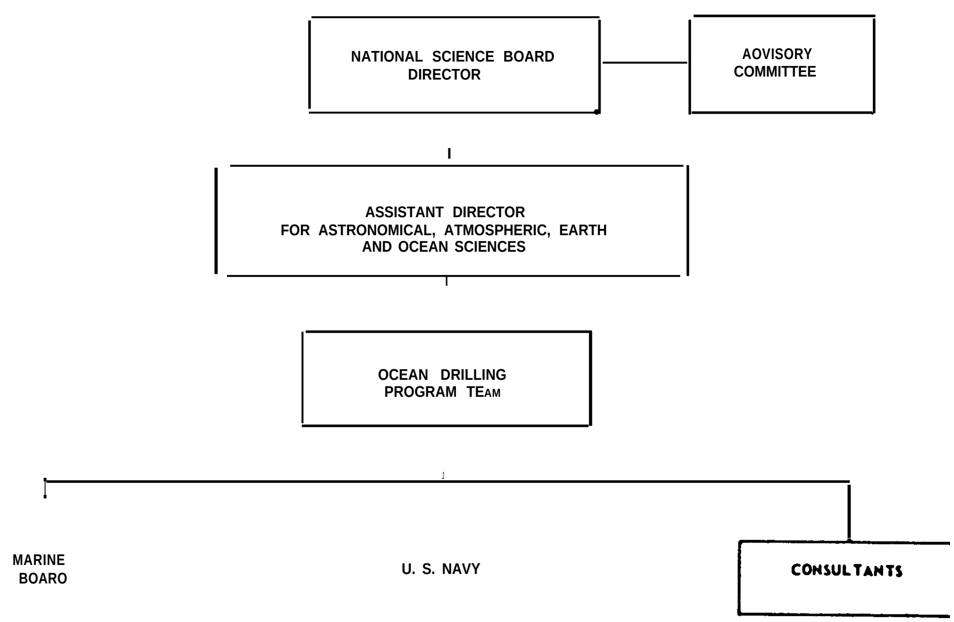
As a result of the inputs from the scientific and engineering studies, the recommendations of the Blue Ribbon Committee, and the prospect of sharing the cost of the program with the oil industry, a revised management structure was established within the NSF to adapt prior management concepts to existing 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

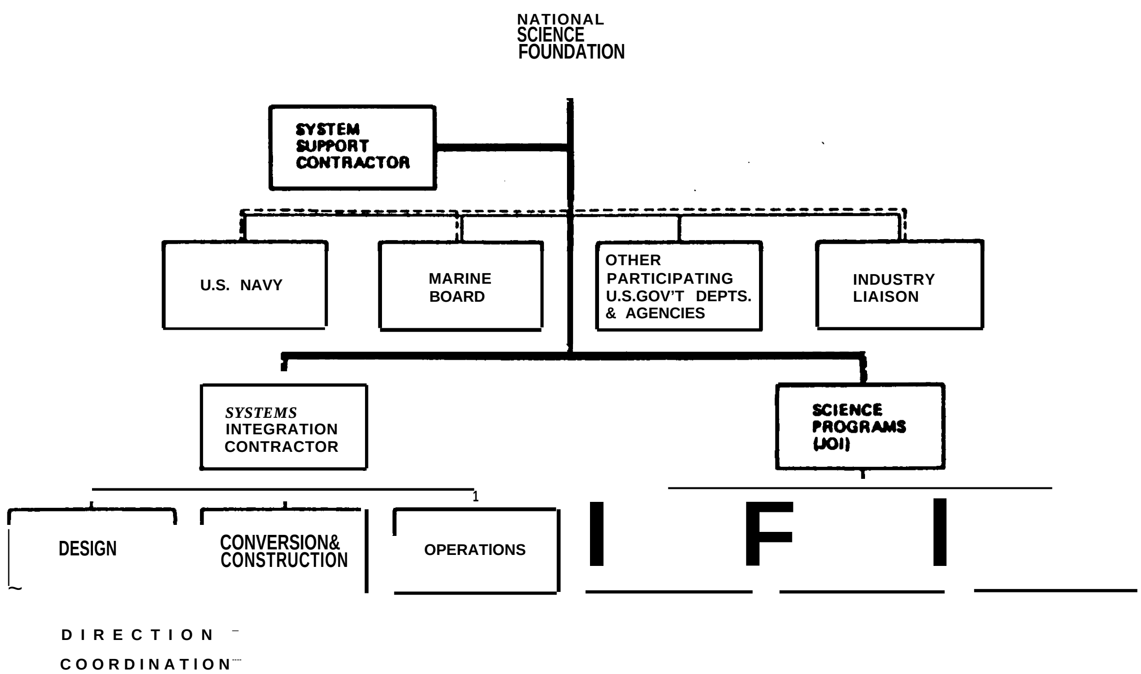
the program as it develops. Figure 5 illustrates the lines of responsibility intended to apply to this combination of management, advisory, and performance groups.

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 aboar 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.**

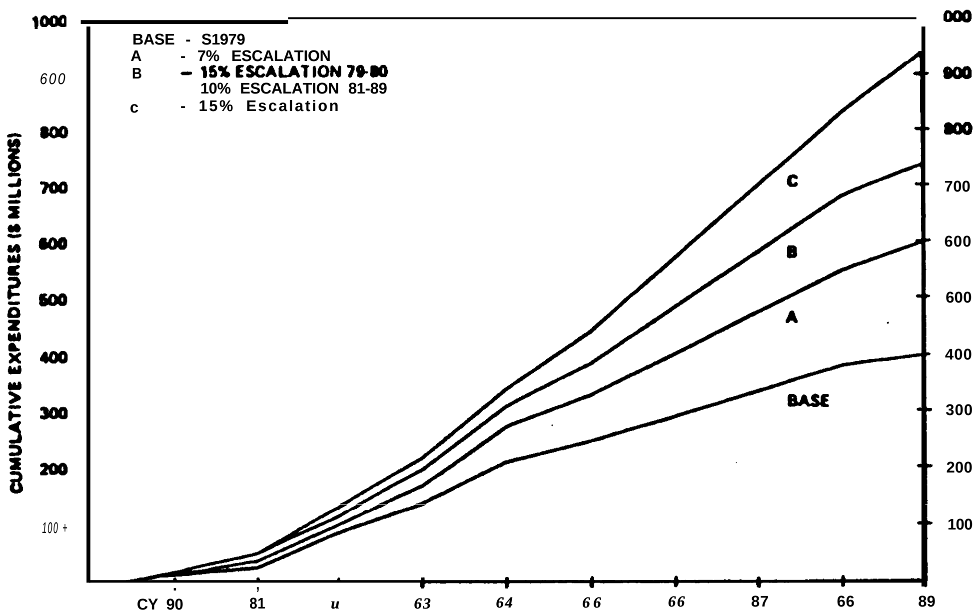
As a. result of this review, the program cost through fiscal year 1989, at a 7% escalation, was estimated to be $615 million which exceeded by $57 mi



OCEAN MARGINS DRILLING PROGRAM RESPONSIBILITY MATRIX

FIGURE 5

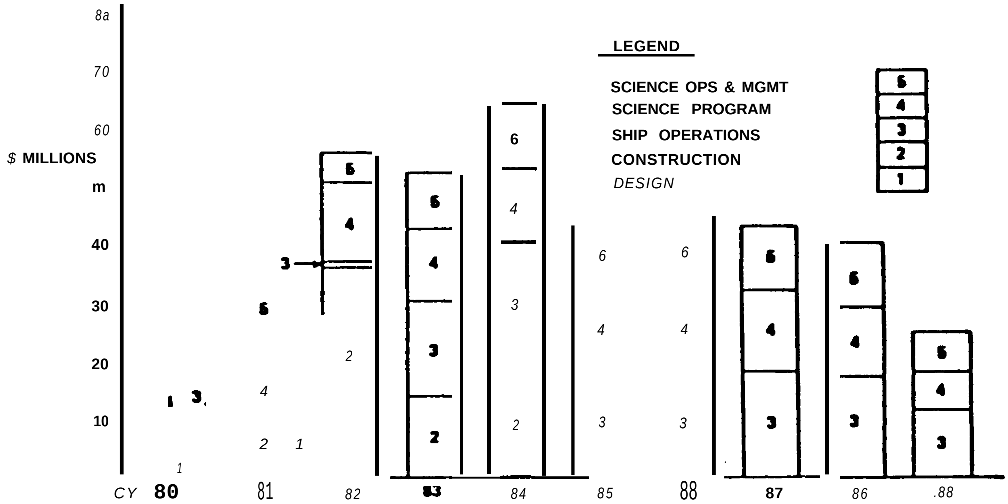
CY	80	81	82	83	84	85	86	87	88	89	PROGRAM
1.0 OMD PROGRAM, 79$	5.3	22.0	56.1	53.8	66.4	46.1	46.8	44.6	42.3	26.8	410.4
ESCALATION @ 7%	.3	3.1	12.6	16.8	26.8	23.1	28.4	32.0	35.6	26.0	204.4
TOTAL @ 7% CASE A	5.6	25.1	68.7	70.6	93.2	69.2	75.3	76.7	78.0	52.8	615.2
ESCALATION @ 15%-10%	.8	5.7	21.9	28.6	45.4	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.

Appendix C

The Hedberg Proposal

Another approach to combining science and oil and gas exploration on the continental margins has been proposed by Dr. Hollis Hedberg of Princeton University in numerous journal and newspaper articles. The following is excerpted from an article in AAPG Explorer of November 1979. Several scientists that OTA has contacted believe this would be a viable approach.

"The program should be a cooperative effort among petroleum companies, with government, and with whoever else can contribute to successful exploration and development in the oceans. What I would recommend, as a supplement to our present system, would be the selection by government (with industry advice) of a number of large regional blocks of relatively promising offshore acreage, going far out into deep water to the base of the continental slope. The size of the blocks would be not the present 5,760 acres, but on the order of millions of acres - still only a small fraction of the nearly one thousand million acres of total U.S. offshore.

"These blocks would be offered to industry Consortiums, without bonus payments, with rights of both exploration and exploitation, with suitable government royalties, and with such exploration commitments for each block as would seem necessary to assure conclusive results. Provisions for tax benefits to offset unsuccessful ventures plus limitations to prevent excessive returns from successful ones would be in order. The operational management would be by the Consortium, working under much the same sort of an arrangement as was used quite successfully by the consortium of companies

in Iran to meet the emergency of the 1950's. There would be a stong central operating unit, made up of selected personnel contributed by the constituent entities and with advisory groups of the Members both for exploration and production.

"The members of the Consortium would each have equal shares and would be entities with requisite experience in offshore Petroleum operations and willing and able to commit to the Consortium as openers X million dollars for exploration over a specified period. These would normally be major oil companies or associations of smaller oil companies. (However, an exception might be made to allow the Federal government (or an appropriately situated state government) to also hold a single equal share under the same terms and commitments as other entities.)

"Finally, a possible further provision might be made to bring into the Consortium a unit composed of the major oceanographic research institutions. The so-called Stever report of the National Science Foundation (1979) calls for a 10-year 600-million-dollar program of drilling for science on the ocean margins with the Glomar Explorer, and proposes that the U.S. petroleum industry should help to foot the bill. (A contribution of about 50 percent has been suggested.) Such a proposal, although indeed able to contribute geological background useful in subsequent petroleum exploration, falls far short of direct on-structure petroleum exploration drilling on already granted lease acreage which, if successful, could be followed promptly by production development. Much more pertinent to solving the country's petroleum problem, while at the same time highly effective in advancing the scientific knowledge of its offshore margins, would be the idea of bringing the combined major oceanographic institutions (JOIDES) into the proposed

Consortium programs as a participating Member at no monetary cost to them and still under conditions where their research and it publication could be strongly encouraged and supported."

Appendix D

Responses From Two Petroleum Companies Which Illustrates Stated Reasons For And Against Participating In The Ocean Margin Drilling Program

Gulf Oil Exploration and Production Company

March 17, 1980

Joseph O.. Carter
SENIOR VICE PRESIDENT
EXPLORATION h TECH NO LO(3Y

P. o. Box 2100
Houston, TX 77001

Mr. Peter A. Johnson
Project Director
congress of the United States
Office of Technology Assessment
Washington, D.C. 20510

Dear Mr. Johnson:

Receipt of your letter of March 12, 1980, is acknowledged wherein you ask for our views concerning the program and aspects of the Margin Drilling Program proposed by the National Science Foundation.

You should know that Gulf elected not to participate in the Program after attending the several meetings with NSF officials. In our view, the scope of the Program is too thinly dispersed to add very much to the general knowledge of our country's resource base. We are certainly in agreement that the resource base needs to be determined. To date, the industry's investigation has been mainly limited to the continental shelves, whereas the continental slopes are virtually untested. The slopes can be evaluated with present drill riser technology. Development of riser technology to drill the abyssal deep within the next ten years is much too soon in our opinion. We do not foresee the industry being anywhere near ready to explore at such depths much less to have the technology to produce hydrocarbons from them in that time frame. Perhaps twenty or thirty years is more realistic on the evolutionary scale since economic feasibility plays a very large role in determining when these things are possible.

I think we would much rather have seen a program in two phases. Phase I would consist of a series of up to ten wells drilled on the continental slope of the North American continent using available technology with a simultaneous world-wide multi-phase seismic survey. Phase II would consist of a drilling program in those prospective areas defined by the seismic survey that would perhaps include some abyssal deep drilling.

Gulf

A DIVISION OF GULF OIL CORPORATION

This is not to say that Gulf's mind is closed to the concept nor to the possibility of ever joining such a project. It is simply that the costs cannot be equated with meaningful results at this time.

1f you require further comment, please let me know. We would be happy to meet with you or your staff at any time that is mutually agreeable.

Very truly yours,

J.O. Carter

~_ J.O. CARTER

JOC : bf

4600 N. Fuller Drive, Ridgeview Plaza, Irving, Texas 75062 (214) 258 4000
Sunmark EXPLORATION COMPANY

April 3, 1980

Mr. Peter Johnson
Project Director
Office of Technology Assessment
Washington, D. C. 20510

RE: Ocean Margin Drilling Program

Dear Mr. Johnson:

Your recent letter in regard to the Ocean Margin Drilling Program is one that we feel merits careful attention, justifying a written response.

Although you did not state the time available in which to complete your response to the HUD-Independent Agencies Subcommittee of the Senate Appropriations Committee, it is assumed that you wish to move forward as promptly as possible.

Sunmark Exploration Company, a Division of Sun Oil Company (Delaware), supports the program. We do have concerns regarding industry level of support (only eight companies have committed in principle to the program) and believe that greater participation by industry will be required to carry the project through. Foreign participation may be available, but will probably be limited.

Sunmark considers the program advantageous in that it combines scientific objectives with the development of new drilling technology. In such a complex program, we feel that the joint effort of government and industry combining knowledge and expertise, while sharing expenses, will give greatest chance for safe and economical progress. We do not expect the program to contribute directly to our knowledge of hydrocarbon resources, as we will not support on-structure drilling.

We do expect to gain knowledge concerning sediments in the areas studied, and certainly will draw conclusions regarding specific areas of opportunity.

If the program is carried out; however, this information will be available to anyone, as results of the research will be published and released to the public shortly after acquisition. Geological and geophysical research that must accompany the program will enable the best utilization of the advanced technology to be developed and support the acquisition of maximum information for the basic research.

The Glomar Challenger drilling program has provided a giant leap in man's knowledge of the earth, with a good understanding of plate tectonics. Practically, some areas of the earth have been identified as having oil and gas potential, and more particularly, the approximate age and thickness of prospective zones. The National Science Foundation has been an excellent management vehicle for The Deep Sea Drilling Program, and with the support of The Oceanographic institutions and the cooperation and support of Industry, should constitute the most effective operation possible for the Ocean Margin Drilling Program.

Yours very truly,

J. E. Thompson

JET\wm