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 <u>Glomar Explorer</u> 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

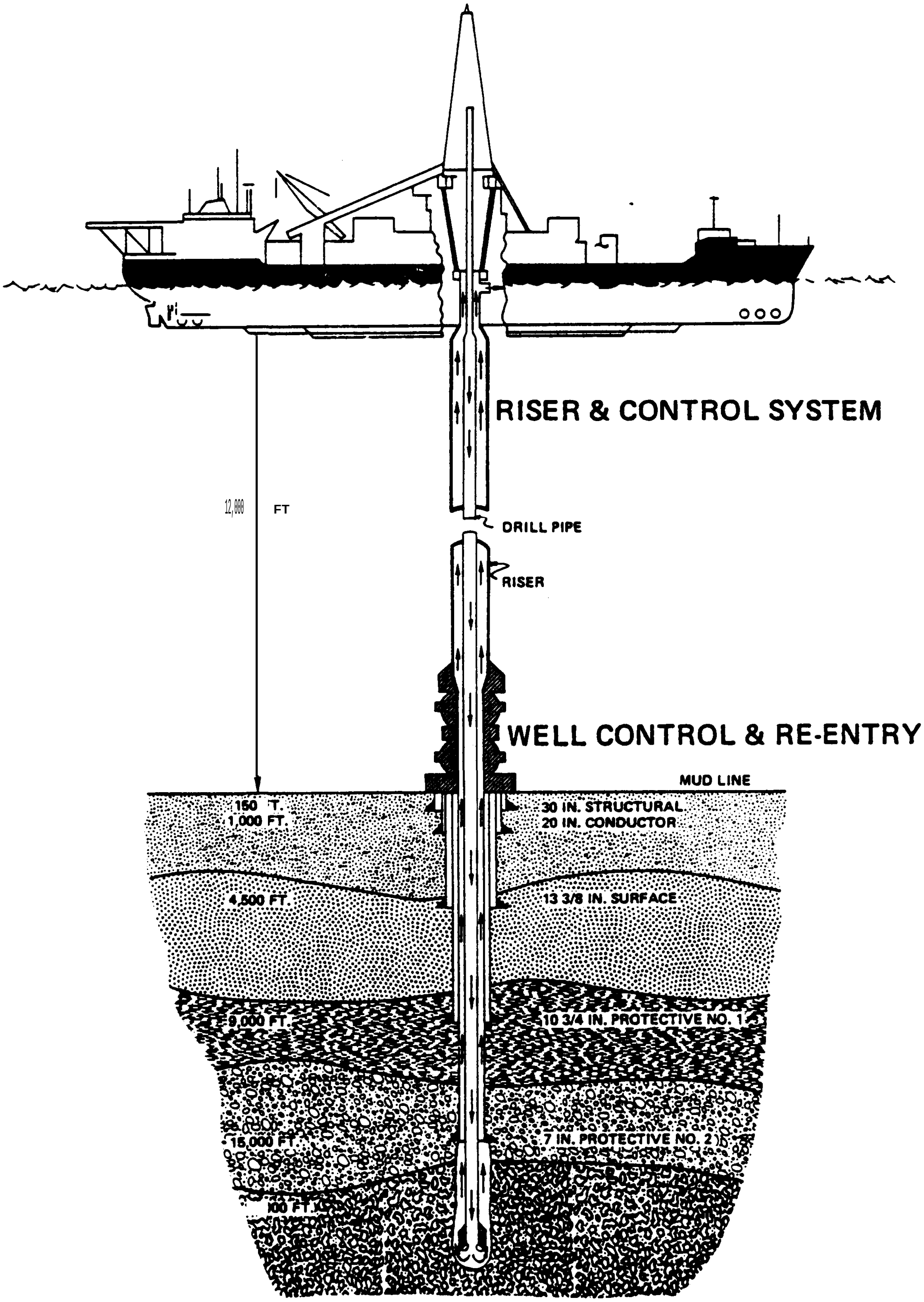
In deep water, drilling with a 30″ or a 20″ casing (and a 16″ casing if it is used) is often done without a riser. Prior to setting a 30″ casing, the riser has no foundation and the casing is usually not sufficiently founded to support the riser loads alone. A small pilot hole is usually drilled prior 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

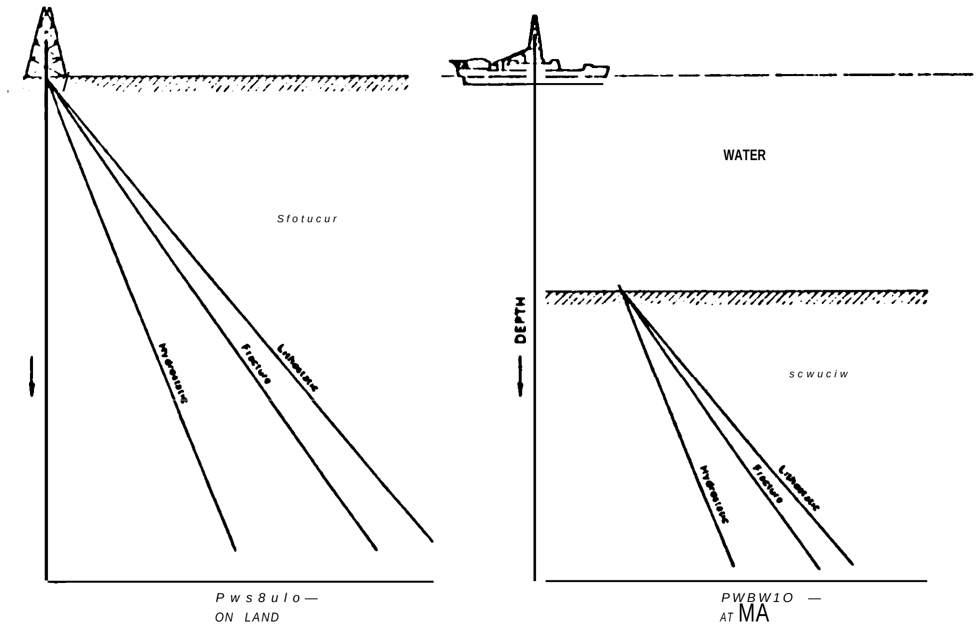
accurately to withstand the sudden increase in pressure and prevent a blowout or uncontrolled flow out of the formation and up the hole.

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.