Resource Evaluation Program Report

OCS Report
MMS 90-0028

The Offshore Deep Stratigraphic Test Well Program

By George Dellagiarino

U. S. Department of the Interior
Minerals Management Service

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ERRATA NOTICE

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Since the publication of this report, the regulations at 30 CFR Part 251, which govern the activities associated with deep stratigraphic test wells, have been revised to increase the depth requirement from 300 feet to 500 feet. They now define a deep stratigraphic test as meaning, "drilling that involves the penetration into the sea bottom of more than 500 feet (152 meters)."

Change Affects: Pages 2, 6, and 8, where referring to depth.

Replace: "...of more than 50 feet (15.2 meters) of consolidated rock or more than 300 feet (91.4 meters) of total penetration."

With: "...of more than 500 feet (152 meters) of total penetration."

For more information, contact George Dellagiarino, Resource Evaluation Division at (703) 787-1526.

MMS **U.S. Department of the Interior**
Minerals Management Service

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Figures

Tables

Acknowledgements

The author would like to thank Dr. Allison R. Palmer and the Geological Society of America for providing the geologic time scale.

Conversion Tables

Note: Most of the numbers cited in the text are offered as approximations. The metric equivalents supplied with these numbers are just that, metric equivalents of approximations, and any numerical precision should not be implied.

meter = feet/3.281

kilometer = mile/0.6214

Acronyms

CDP - Common Depth Point
CFR - Code of Federal Regulations
COST - Continental Offshore Stratigraphic Test
DOI - Department of the Interior
EIS - Environmental Impact Statement
FY - Fiscal Year
G&G - Geological and Geophysical
GOM - Gulf of Mexico
MMS - Minerals Management Service
OCS - Outer Continental Shelf
USGS - U.S. Geological Survey

Chapter 1: Introduction

The Minerals Management Service (MMS) is primarily responsible for administering the Department of the Interior's (DOI) role in activities associated with mineral resource development on the Federal Outer Continental Shelf (OCS). These activities relate to the leasing, exploration, development, production, and royalty management of these mineral resources. The primary responsibility of the MMS Resource Evaluation Program is to investigate the mineral potential of the OCS, predominantly for oil and gas, and to assure the receipt of fair market value for oil and gas leases on the OCS. An integral part of this responsibility is the Deep Stratigraphic Test Well Program. This report describes the authority behind the program, as well as the program's functions, operations, and requirements.

A. Statutory Authority

Jurisdiction over the offshore lands is divided between the Federal Government and the coastal States. In response to public concerns about the ownership and development of offshore resources, Congress enacted two laws in 1953, the Submerged Lands Act and the Outer Continental Shelf Lands Act. These laws granted certain offshore lands to coastal States and provided a framework for regulating and managing exploration, development, and production of resources under the seabed beyond the area managed by the coastal States.

B. Regulatory Authority

The MMS administers the provisions of the OCS Lands Act, as amended, through regulations found in Title 30 of the Code of Federal Regulations (CFR). The regulations govern leasing, permitting, collecting of data, and operations on the OCS. For the Resource Evaluation Program, authority has been vested in the Secretary of the Interior under 30 CFR Part 251 to regulate the conduct of prelease geologic and geophysical (G&G) exploration for mineral resources on the OCS. Part 251 applies not only to G&G exploration but to scientific research as well. The purpose of these regulations is (1) to prescribe when a permit or the filing of a statement of intent to conduct G&G exploration on the OCS is required and (2) to prescribe operating procedures and requirements for conducting exploration, conditions for reimbursing permittees for certain costs, and other conditions under which exploration shall be conducted. Activities involving the drilling of deep stratigraphic tests are regulated under 30 CFR Part 251, primarily at 30 CFR 251.6-2 through 251.6-5.

C. Resource Evaluation Program

The Resource Evaluation Program consists of three components: (1) G&G Data Acquisition, Evaluation, and Analyses, of which the Deep Stratigraphic Test Well Program is a part; (2) Resource Economic and Engineering Evaluation Analyses; and (3) Reserve Inventory and Analyses. Through these program components, the overall primary objectives of the Resource Evaluation Program are:

- To identify areas favorable for the accumulation of hydrocarbons and to provide information on the distribution of offshore resources and the hydrocarbon potential of the OCS.

- To acquire and analyze scientific data and information in order to develop a basic knowledge of the geologic history and its effect on hydrocarbon generation distribution, and accumulation in the OCS.

- To provide scientific data and information concerning offshore lands to assure an adequate data base is available to the Secretary to make informed decisions regarding the stewardship of the OCS.

- To provide estimates of undiscovered mineral resources, exploration and development scenarios, and economic parameters and statistical data for the OCS to assess the impacts of the objectives of the OCS Lands Act and its' Amendments.

- To develop and maintain an accurate data base of estimates for proven and indicated oil and gas reserves, as mandated by the OCS Lands Act and its' Amendments, and an inventory of hypothetical and speculative oil and gas resources.

- To provide resource economic evaluations and bid adequacy determinations for blocks bid upon in lease sales to assure that the Government receives fair market value for leased offshore lands.

- To provide sound analytical and technical support to the offshore program, including postlease regulatory activities, so that all activities can be carried out effectively and efficiently.

D. Geologic and Geophysical Data Acquisition and Analysis

Generally, the objective of acquiring and analyzing G&G data is to identify areas and tracts that have potential for the occurrence of oil, gas, sulphur, and strategic/critical minerals. The data acquired form the basis for mapping and evaluating the quantity and distribution of potential offshore resources and for assuring receipt of fair market value for lands leased.

Industry collects prelease G&G data in compliance with permits issued through the MMS Resource Evaluation Program. Pursuant to conditions of the permit, the collected data are selectively acquired by the MMS to directly support analyses required throughout the leasing process (see figure 1). In addition to well logs and other data acquired as a condition of a lease, MMS also acquires prelease data from deep stratigraphic tests, bottom sampling, shallow test drilling, aeromagnetic and gravity surveys, and common depth point (CDP) seismic surveys. These data are carefully analyzed and interpreted in proposed lease sale areas to determine the areas of hydrocarbon potential, to specifically locate and map geologic structures capable of trapping hydrocarbons, and to establish values for the geologic parameters necessary for resource assessment and economic evaluation to support leasing decisions.

Seismic data provide the primary data base required for identifying and evaluating an area. The existing seismic data base in a planning area is not only used for outputs related to a specific sale, but is supplemented with new or additional data and used for later sales in the same planning area (see figure 2).

E. The Deep Stratigraphic Test Well Program

As part of prelease G&G data acquisition and analysis, the Deep Stratigraphic Test Well Program involves the drilling of a well into the sea bottom to a depth of more than 50 feet (15.2 meters) of consolidated rock or more than 300 feet (91.4 meters) of total penetration. The information gathered is used for evaluating tracts to be offered in an upcoming lease sale. This drilling is usually done by a consortium of companies with one serving as the operator. These wells are also referred to as continental offshore stratigraphic test (COST) wells.

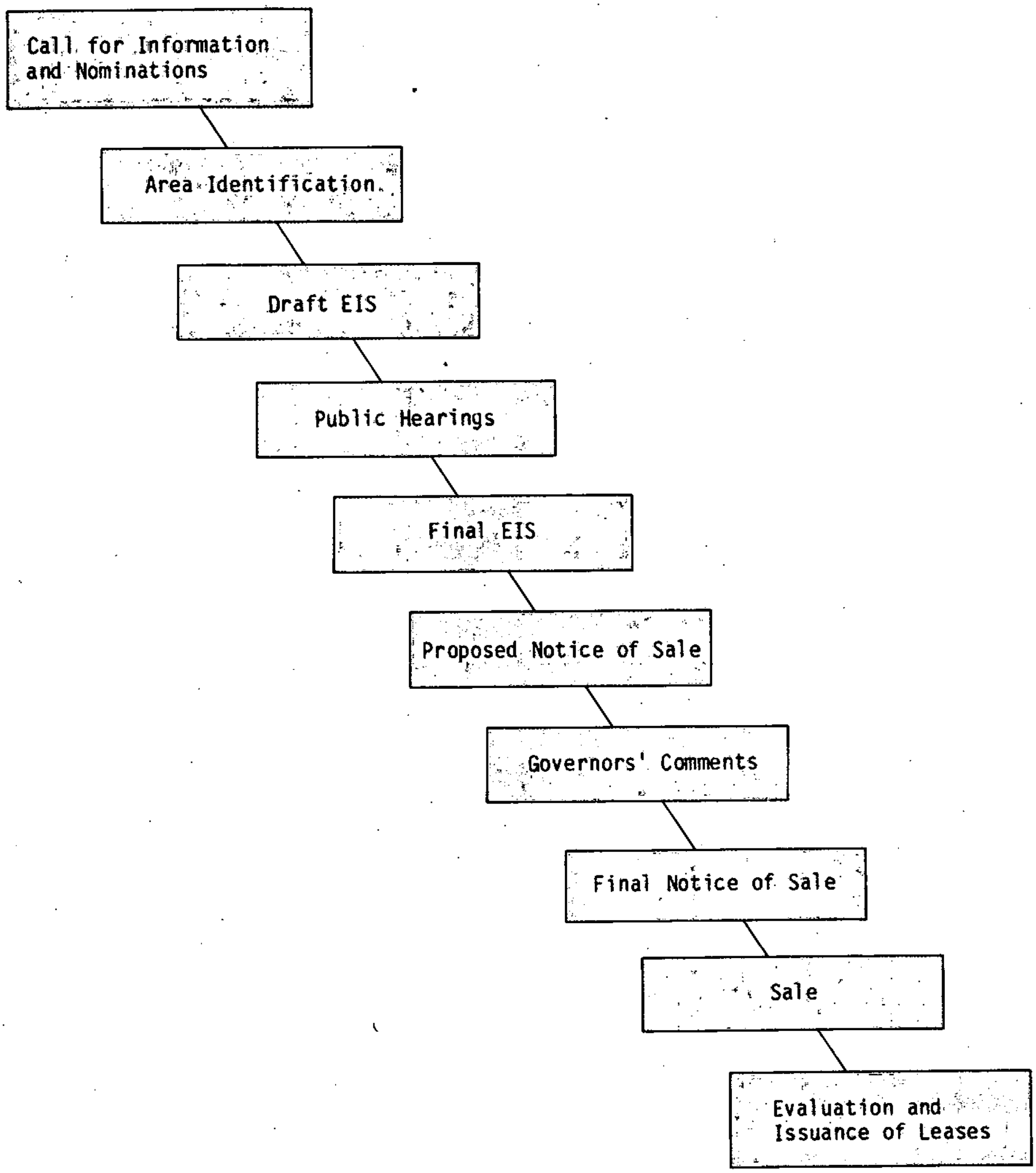

FIGURE 1. Leasing Procedures and Milestones

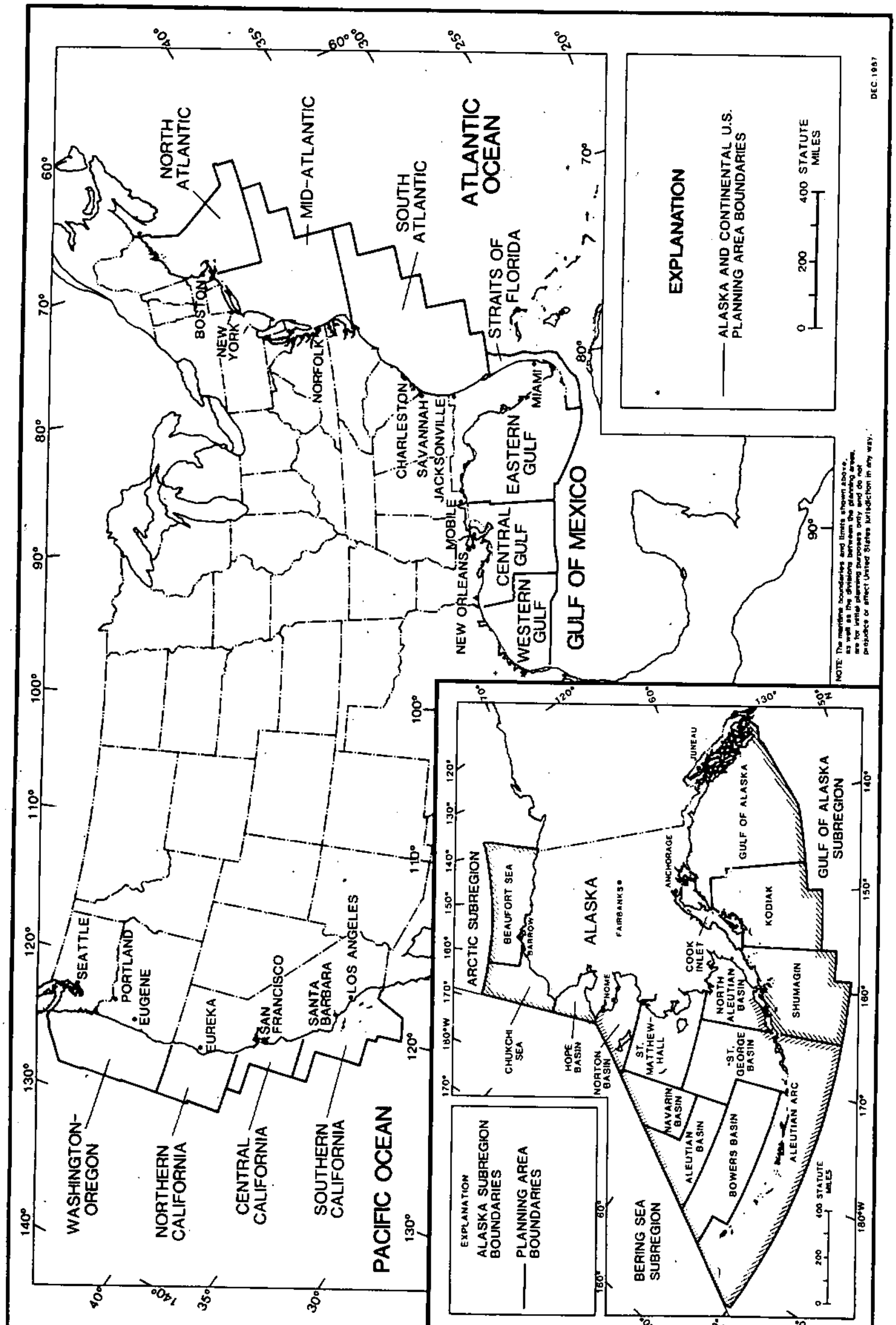

FIGURE 2. Federal OCS Planning Areas

Chapter 2: Prelease Geological and Geophysical Data

Deep stratigraphic tests are administered under 30 CFR Part 251 and are just one data collection method these regulations oversee. Authority is exercised by the Secretary of the Interior through 30 CFR Part 251 to regulate prelease G&G exploration and scientific research for mineral resources on the OCS. These regulations encompass general prelease requirements of notices or permits for G&G exploration, scientific research, test drilling activities, operating particulars and reporting requirements. Industry collects prelease G&G data in compliance with these regulations and permits issued through the OCS Resource Evaluation Program. The collected data are inspected and selectively acquired by the MMS to directly support analyses required throughout the leasing process. The following describes the different types of surveys and prelease activities.

A. Geophysical Surveys

1. Seismic Reflection - CDP seismic reflection is the measurement of the two-way travel time of seismic waves from the ocean's surface to various rock formations within the earth. Information is collected about the thickness and depth of various formations or strata of rock and the probable location and existence of structural features such as reefs, salt domes, folds and faults, and stratigraphic traps.

   Most recently, developments in seismic surveys include sophisticated data processing and three-dimensional (3-D) surveys where various methods are used to collect additional data between tracks during a survey, thus producing more dense subsurface information. The most common use of these surveys is to more precisely delineate the desired subsurface targets of exploratory wells and to shorten the time between a discovery and subsequent production.

   Prelease use of 3-D survey techniques was originally limited primarily to speculative surveys by geophysical companies due to the added costs of surveying and especially processing. This has changed, however, and within the last several years, 3-D surveys have mostly been conducted by the oil and gas industry.

2. Gravity - Variations in the earth's gravity as measured from a ship indicate differences in density of subsurface rocks at various depths. Gravity data are used to delineate gross features and are used commonly with other methods to assess regional geology and to locate salt domes, sedimentary basins, and deep basement rock.

3. Magnetics - Magnetic prospecting methods map anomalies caused by changes in physical properties of subsurface rocks. Their most extensive uses in oil exploration have been for outlining areas of maximum thickness of potentially oil bearing sediments and for mapping deep basement structures that lie beneath a thick cover of sediments.

B. Geologic Surveys

1. Bottom Sampling - Bottom samples are obtained by dropping a weighted tube to the ocean floor and recovering it with an attached wire line. Depending upon the nature of the ocean floor, penetration is normally limited to a few tens of feet. Bottom samples can also be obtained from dredging.

2. Shallow Coring - Shallow coring is performed by conventional rotary drilling

equipment to obtain a near-surface sample of the rocks of the seabed. The location is carefully chosen to avoid any shallow (geological and manmade) hazards, for example, faults or environmentally sensitive areas. Penetration is limited to 50 feet (15 meters) of consolidated rock or a total of not more than 300 feet (91.4 meters).

3. Deep Stratigraphic Test Wells/Continental Offshore Stratigraphic Test (COST) Wells - In any planning area, deep stratigraphic test wells, commonly known as COST wells, can be drilled to determine the geological character of rock strata. The location of such wells is carefully controlled by a permit issued by the MMS. These tests, which may be more than 20,000 feet (6,096 meters) deep, provide information that can be used by the Government and industry to evaluate tracts to be offered in a lease sale. Basically, an operator sets up a consortium with other companies where drilling costs are shared. The wells are drilled in accordance with MMS regulations. All stratigraphic tests must be completed no later than 60 days before a lease sale, and the information is released to the public 25 years after completion of the well or 60 calendar days after the issuance of the first oil and gas lease within 50 miles (92.6 kilometers) of the well site, whichever occurs first.

C. Permitting

Under the OCS Lands Act, the issuance of exploration permits is required. Section 11 of the OCS Lands Act provides for prelease G&G activities.

> Any agency of the United States and any person authorized by the Secretary may conduct geological and geophysical explorations in the outer Continental Shelf, which do not interfere with or endanger actual operations under any lease maintained or granted pursuant to this Act, and which are not unduly harmful to aquatic life in such area.

The 1978 amendments to the Act added subsection (g) to section 11 authorizing the Secretary to issue regulations for permitted activities. The regulations at 30 CFR Part 251 govern the prelease activities pursuant to the OCS Lands Act. Section 251.4-1 requires a permit for prelease exploration activities. It provides in part that

> Geological or geophysical exploration for mineral resources may not be conducted on the OCS without an approved permit unless such activities are being conducted pursuant to a lease issued or maintained under the Act.

As shown in figure 3, the procedure for processing and approving OCS exploration permits includes

- Review of application for permit to conduct OCS exploration for mineral resources or scientific research;

- Issuance of permit including terms, conditions, and stipulations;

- Timely correspondence with each permittee; and

- Monitoring permit activity.

Operators seeking a permit to drill a deep stratigraphic test must adhere to these procedures.

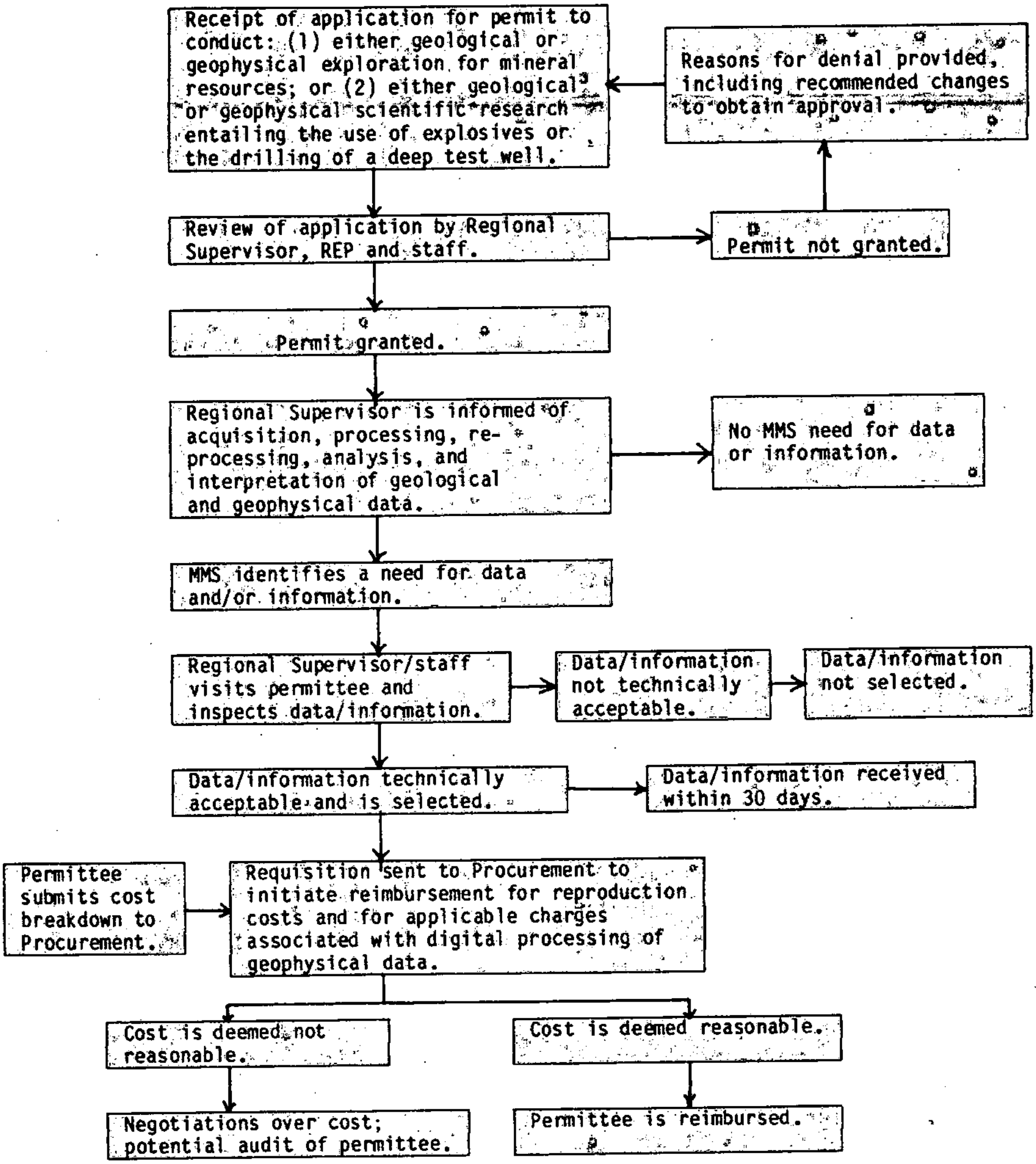

FIGURE 3. MMS Acquisition of Geological and Geophysical Data and Information as a Condition of Permits and Regulations

Chapter 3: Deep Stratigraphic Test Program

A deep stratigraphic test, as defined in 30 CFR 251, "means drilling which involves the penetration into the sea bottom of more than 50 feet (15.2 meters) of consolidated rock or a total of more than 300 feet (91.4 meters)." Conversely, shallow test drilling, as defined in the same regulations, "means drilling into the sea bottom to depths less than those specified in the definition of a deep stratigraphic test."

A. Purpose and Methods

Since 1974, the DOI has permitted deep stratigraphic test drilling at industry initiative on the OCS prior to Federal leasing. These deep stratigraphic tests are not necessarily designed to discover oil and gas, but rather to obtain information about the nature of the subsurface rock layers, which will improve geologic interpretations of the potential for hydrocarbons in a particular offshore area.

Regulations for these deep stratigraphic tests (in 30 CFR 251) provide that

- The program be advertised for 30 days to invite participation in a consortium on a cost-sharing basis. Participation is open to any interested party.
- One participating company acts as the operator for the consortium.
- Late participants are admitted, but with a penalty not to exceed 100 percent of the cost to an original participant plus the original cost share. If the Director of the MMS announces a significant hydrocarbon occurrence, the penalty for subsequent late participants may be raised to not more than 300 percent of the cost of each original participant plus the original cost share.
- The test location and a drilling plan are proposed by the operator or consortium, subject to approval by the MMS.
- The test location may be on- or off-structure.
- If the test encounters a significant show of hydrocarbons, the Director of the MMS immediately issues a public notice to that effect.
- All data from the test are furnished to the Government for reproduction costs.
- Data from the test are made publicly available (1) 25 years after the date of completion of the test or (2) following completion of the well, 60 days after the issuance of the first Federal lease within 50 miles (92.6 kilometers) of the drill site, whichever is earlier.

Originally, deep stratigraphic tests were only allowed to be drilled off-structure. In November 1978, the Secretary announced his intention to allow the drilling of prelease test wells on- or off-structure, citing the ability to obtain substantially better information to improve the estimation of the potential of offshore oil and gas provinces. Regulations governing on-structure drilling became effective in January 1980. To date, however, no on-structure deep stratigraphic tests have been drilled. One possible explanation might be that in a frontier area where industry is trying to determine drilling conditions and costs, an on-structure test may not provide better information on variables such as porosity, permeability, water saturation, etc., if the stratigraphic section has been deformed by the geologic structure.

B. Completed Wells

Twenty-four deep stratigraphic test wells have been drilled to date (see figures 4 and 5). The breakout is as follows: Alaska (14), Atlantic (5), Gulf of Mexico (3), Pacific (2). The wells are listed in table 1.

Hydrocarbon shows have been announced for three wells, the COST B-3 well in the Atlantic, the Point Conception No. 1 well in the Pacific, and the Norton COST No. 2 well in Alaska.

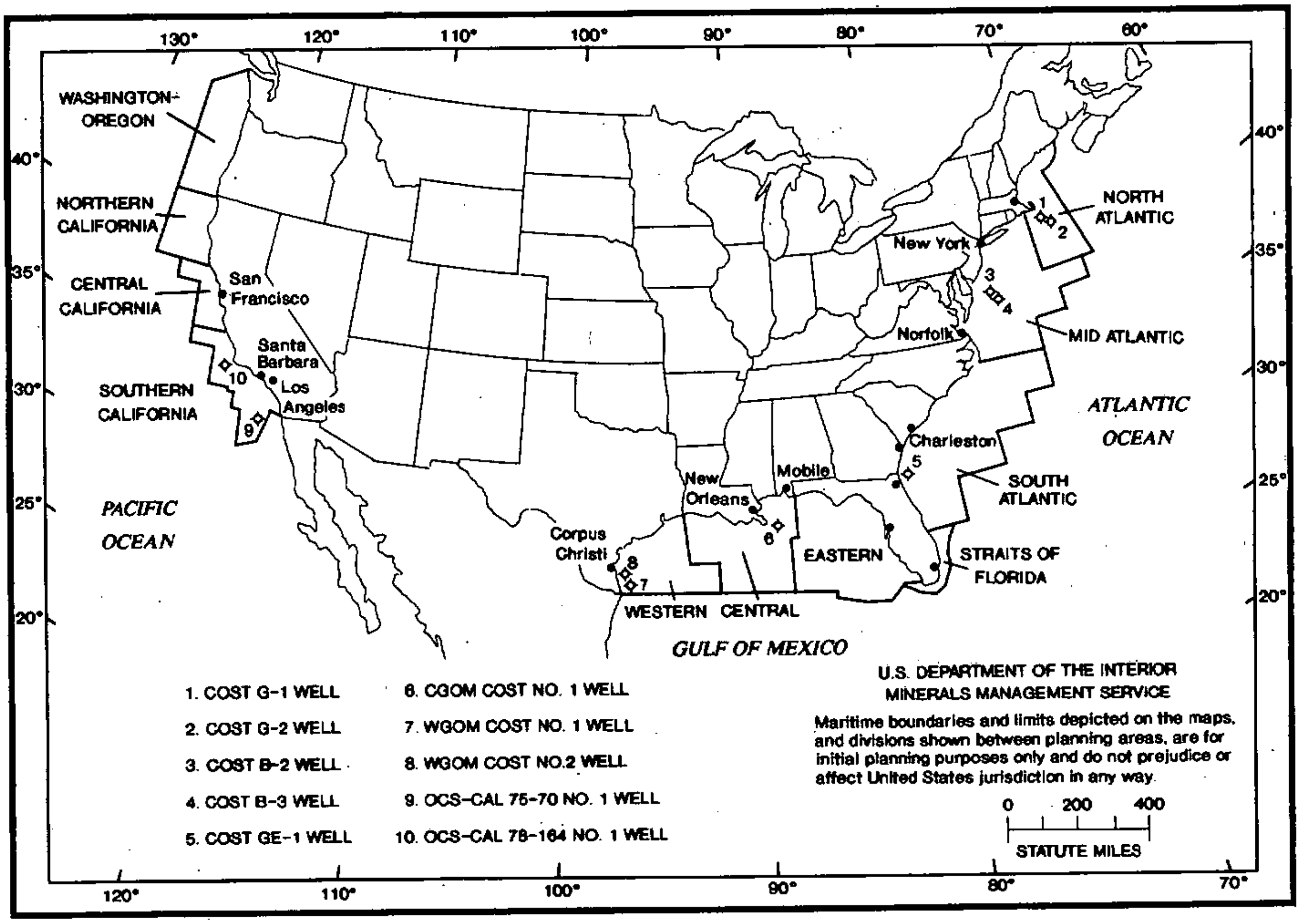

FIGURE 4. Location of COST Wells - Lower 48 States

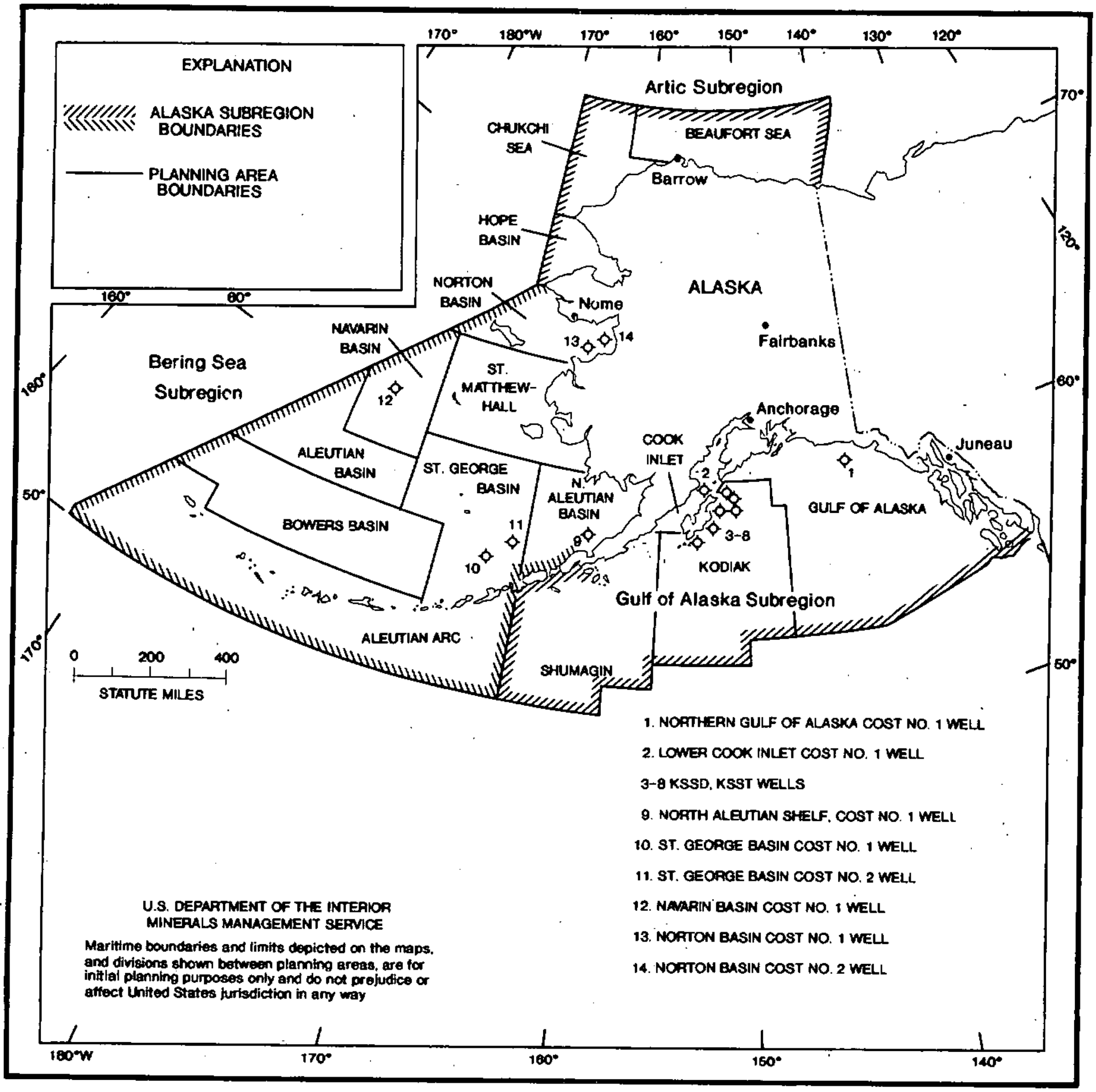

FIGURE 5. Location of COST Wells - Alaska

Table 1. Listing of Deep Stratigraphic Tests

OCS Area	Well No.	Completion Date
Atlantic		
North Atlantic	COST No. G-1	July 1976
	COST No. G-2	August 1977
Mid-Atlantic	COST No. B-2	March 1976
	COST No. B-3	January 1979
South Atlantic	COST No. GE-1	June 1977
Gulf of Mexico		
Central Gulf	COST No. 1	September 1989
Western Gulf	COST No. 1	November 1974
	COST No. 2	February 1975
Pacific		
S. California	Cal. 75-70 No. 1	December 1975
S. California	Pt. Conception Cal. 78-164 No. 1	December 1978
Alaska		
N. Gulf of Alaska	COST No. 1	October 1975
Lower Cook Inlet	COST No. 1	September 1977
Kodiak	KSSD - 1	July 1977
	KSSD - 2	September 1977
	KSSD - 3	October 1977
	KSST - 1	August 1976
	KSST - 2	August 1976
	KSST - 4A	September 1976
N. Aleutian Shelf	COST No. 1	January 1983
St. George Basin	COST No. 1	October 1976
	COST No. 2	September 1982
Norton Sound	COST No. 1	September 1980
	COST No. 2	August 1982
Navarin Basin	COST No. 1	October 1983

A show of gas was encountered in the COST B-3 well in a sandstone interval from 15,744 feet (4,799 meters) to 15,752 feet (4,801 meters). Significant shows of oil and gas were encountered in the Point Conception No. 1 well from 1,850 feet (564 meters) to 4,000 feet (1,219 meters). The Norton COST No. 2 well encountered shows of gas between 12,040 feet (3,670 meters) and 12,450 feet (3,795 meters).

C. Regulatory Requirements

Deep stratigraphic test wells are drilled in accordance with regulations at 30 CFR 251. Activities associated with the drilling must be conducted so that those activities do not (1) interfere with operations on a lease, (2) harm or damage aquatic life, (3) cause pollution, (4) create hazardous conditions, (5) interfere or harm other uses of the area, or (6) disturb archeological resources. When drilling a deep stratigraphic test, the operator must report to the Director of the MMS when the activities (1) indicate hydrocarbons, (2) encounter environmental hazards, or (3) adversely affect the environment.

1. Permit Requirements for a Deep Stratigraphic Test

No deep stratigraphic test activities will begin until a drilling plan has been submitted by the applicant and approved by the Director, MMS. The drilling plan should include the following:

- Type and sequence of drilling activities, including a timetable for their performance.
- A description of the rig to be used, including safety features, oil-spill cleanup equipment and plans, pollution prevention features, etc.
- Surface and projected bottomhole location(s) of the proposed well.
- Types of geophysical instrumentation to be used and the data and information sufficient to evaluate seafloor characteristics, shallow geologic hazards, and structural detail in the vicinity of the well.
- Any other relevant information required by the Director, MMS.

At the same time the applicant submits the drilling plan, an environmental report must be submitted. The report will include, in summary form, the following:

- Lists and descriptions of new or unusual technologies to be used, supply travel routes, kind and quantities of energy to be used, monitoring systems, and suitable maps and diagrams of the project layout.
- A narrative describing the geology, physical oceanography, flora, fauna, environmental monitoring systems, other area uses, and other characteristics affected by drilling.
- A narrative describing probable impacts and proposed mitigating measures.
- A narrative describing any unavoidable or irreversible adverse affects on the environment.
- Any other relevant information required by the Director, MMS.

The operator may be required to conduct studies to determine if cultural resources exist in the area. In any case, all regulations related to drilling operations pursuant to 30 CFR 250 will apply.

2. Group Participation

To allow for group participation the applicant must publish a summary statement describing the proposed activity and allow at least 30 days for other participants to join. The estimated cost of the well can then be divided among the original participants. A list of all original participants and late participants will be forwarded to the Director, MMS. If, for some reason, the applicant proposes changes in the original application, the MMS may require a republication of the changes and an additional 30-day notice.

Late participants will pay a penalty not to exceed 100 percent of the cost to each original participant plus the original share cost. If a significant hydrocarbon occurrence is announced, the penalty for late participation may be raised to not more than 300 percent of the cost to each original participant plus the original share cost.

3. Bonds

Before a permit is issued, the applicant must submit a corporate surety bond in amounts in accordance with 30 CFR 256 Subpart I. It should be conditioned on compliance with terms of the permit issued to the applicant for the area of the OCS where the deep stratigraphic test is proposed.

4. Duration of Activities and Final Report

Each permittee submits a final report of exploration activities under the permit to the Director, MMS, within 30 days of the completion of the well. The report will include a description of the work, charts, maps, and graphs, dates of the activities, and a summary of any hydrocarabon occurrences, adverse effects, or environmental hazards.

All data and information from the well are submitted to the Director, MMS, at least 60 days before the first day of the month in which a lease sale is scheduled in that area. The permittee will be reimbursed for the reproduction costs of all information.

5. Disclosure of Information to the Public

The Director, MMS, will make all data and information obtained from a deep stratigraphic test available to the public (1) 25 years after the completion of the well or (2) following the completion of the well, 60 calendar days after the issuance of the first oil and gas lease within 50 miles (92.6 kilometers) of the well site, whichever is earlier.

Chapter 4: Summary of Deep Stratigraphic Test Drilling Results

The following summary of drilling results is taken from the OCS (MMS) and Open-File (USGS) reports for the various COST wells listed in the "selected references" section (references are indicated following each discussion). The individual summaries vary in length and detail because later reports tend to be more descriptive than the earlier ones and the deeper wells have more information to present than the shallower ones.

A. North Atlantic COST No. G-1 Well

The COST No. G-1 well was drilled to total depth of 16,071 feet (4,898 meters) in the Georges Bank Basin about 89 nautical miles (143 kilometers) east of Nantucket Island, Massachusetts. The G-1 was drilled by the semisubmersible rig SEDCO J in 157 feet (48 meters) of water at a total cost of about $8 million. The well was begun on April 6, 1976, and drilling was completed July 17, 1976, the first deep well to be drilled in the Georges Bank Basin. Ocean Production was the operator for 31 total participants.

Five conventional cores were obtained along with 687 sidewall cores, of which 3 conventional and 117 sidewall cores were analyzed. Ditch cuttings were also obtained and analyzed.

The COST No. G-1 well is divided into seven major lithologic sections. Section I, from 1,030 to 6,250 feet (314 to 1,905 meters), consists of Cretaceous and Upper Jurassic (see figure 6) sand, gravel, sandstone, shale and thin beds of dolomite deposited in deltaic and shallow or marginal marine to middle shelf environments. Section II occurs from 6,250 to 9,940 feet (1,905 to 3,030 meters) and contains a sequence of pre-dominantly Upper Jurassic shaly sandstones, shales and limestones and dolomites deposited in tidal flat to shallow marine environments. Section III, 9,940 to 11,900 feet (3,030 to 3,627 meters), consists of Upper and Middle Jurassic oolitic limestones, shales, calcareous sandstones, and minor amounts of coal, deposited in tidal flats and shallow carbonate banks. Section IV, 11,900 to 12,360 feet (3,627 to 3,767 meters), contains Middle Jurassic sandstones, shales, limestones, dolomites and minor coals deposited in tidal flats and shallow marine waters. Section V, from 12,360 to 13,610 feet (3,767 to 4,148 meters), consists of Middle Jurassic dolomite, sandstone, anhydrite, and shale deposited in a sebkha to shallow marine environment and Section VI, 13,610 to 15,600 feet (4,148 to 4,755 meters), contains mostly Lower Jurassic dolomites, sandstones, shales with minor anhydrite deposited in continental to shallow marine waters. Section VII, from 15,600 to 16,071 feet (4,755 to 4,898 meters), consists of metadolomites, metaquartzites, phyllite and gneiss, which are Paleozoic basement rocks.

Several different types of electric logs were run in the G-1 well to obtain petrophysical data. Log analysis indicated a total of 4,230 feet (1,289 meters) of porous rock of reservoir potential (greater than 8 percent pore space) in the well, of which 99 percent occurs above 10,000 feet (3,048 meters). Below this depth, the pore spaces become increasingly filled with calcite, quartz, and clays. The best combination of potential reservoir rocks and sealing beds occurs between 5,200 and 9,940 feet (1,585 to 3,030 meters).

A thermal gradient of 1.17°F per 100 feet was calculated for the well, slightly lower than values of other western Atlantic basins. A pressure gradient of 0.438 pounds per square inch (psi) per foot was calculated and is similar to that in other Atlantic wells.

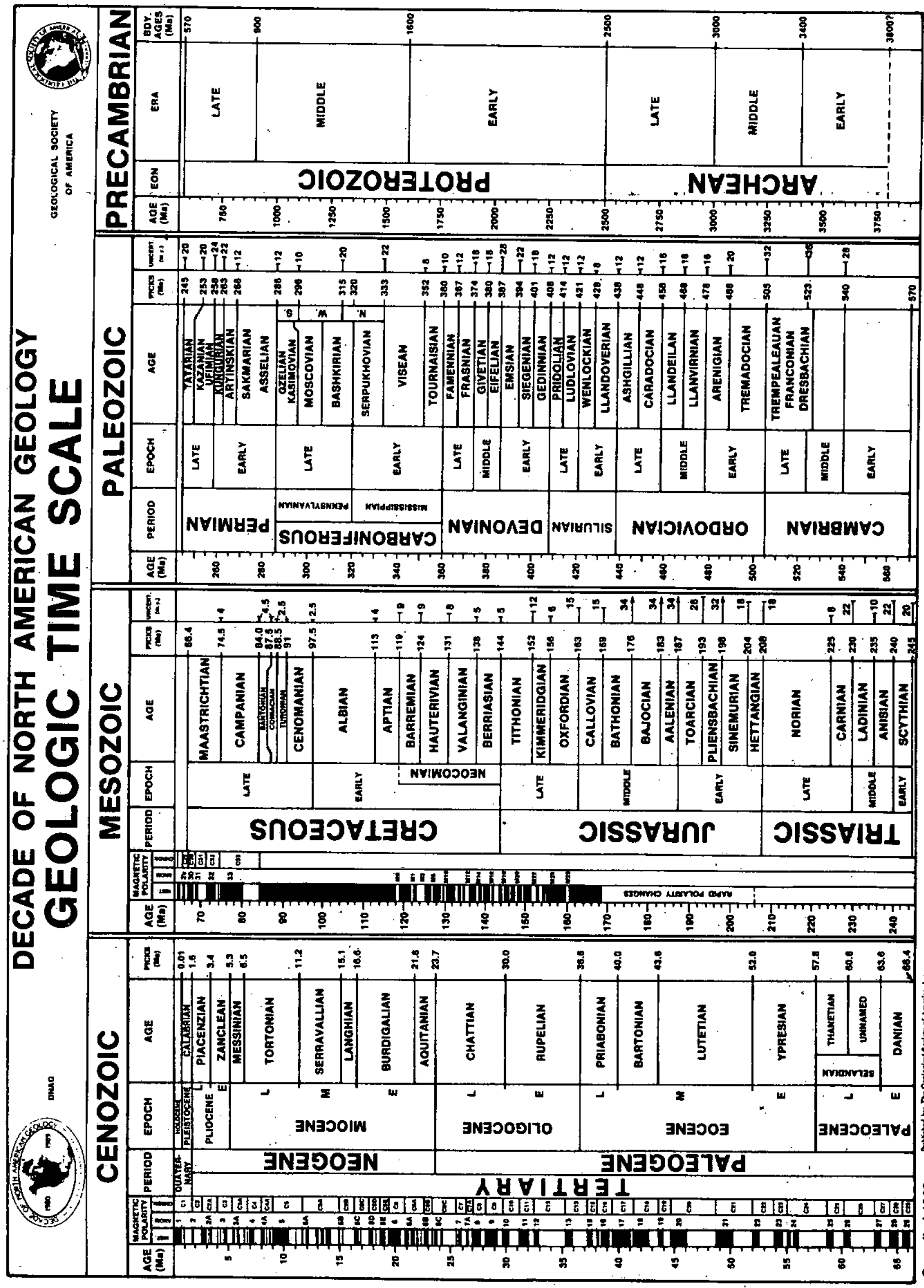

FIGURE 6. Geologic Time Scale

Geochemical data from the G-1 indicate that the organically richest rocks (gas-prone) occur between 4,600 and 6,200 feet (1,402 and 1,890 meters) (Lower Cretaceous and Upper Jurassic), but they are thermally immature. However, the deeper, thermally mature Jurassic rocks are lean in organic matter. The best potential petroleum reservoirs occur in the sandstones above 10,000 feet (3,048 meters), where core and log porosities of 20 percent or more and permeabilities over 100 millidarcies are common. Below 10,000 feet (3,048 meters), porosities and permeabilities are reduced drastically as limestone, dolomite, shale, and anhydrite become the predominant lithologies. (Amato and Bebout, 1980).

B. North Atlantic COST No. G-2 Well

The COST No. G-2 well was drilled to a total depth of 21,874 feet (6,667 meters) in the Georges Bank Basin about 132 statute miles (212 kilometers) east-southeast of Nantucket Island, Massachusetts, and 42 miles (68 kilometers) east of the G-1 well. The G-2 well was drilled by a semisubmersible rig, the Ocean Victory in 272 feet (83 meters) of water for a total cost of $13.9 million. The well was begun on January 6, 1977, and was completed on August 7, 1977. Ocean Production was the operator for 19 total participants.

Electric logs, drill-stem tests, sidewall cores, nine conventional cores, and ditch cutting samples were obtained and analyzed.

From 1,100 feet (335 meters) (Miocene), where sampling started, to 1,620 feet (494 meters) (Upper Cretaceous), the G-2 well penetrated unconsolidated coarse sand and fossiliferous clayey siltsone. The Upper Cretaceous sequence between 1,620 and 2,340 feet (494 to 714 meters) is composed of calcareous, fossiliferous claystone and clayey siltstone. The predominantly Lower Cretaceous section from 2,340 to 3,950 feet (714 to 1,204 meters) ranges from very coarse unconsolidated sand, fine sandstone, and coquina in the upper part to glauconitic silty claystone in the lower part. Limestone between 3,950 and 4,500 feet (1,204 and 1,372 meters) ranges from bioclastic and oolitic grainstone to clayey micrite and calcareous claystone. Massive, weakly cemented, glauconitic sandstones between 4,500 and 5,320 feet (1,372 to 1,621 meters) are interbedded with minor gray shale. The Lower Cretaceous lithologic unit from 5,320 to 5,760 feet (1,621 to 1,756 meters) consists of gray calcareous shale interbedded with coarse to fine sandstone.

The basal Cretaceous to uppermost Jurassic section from 5,760 to 7,000 feet (1,756 to 2,133 meters) is composed of gray to brown micrite and minor oolitic zones interbedded with gray shale and minor sandstone. From 7,000 to 9,580 feet (2,133 to 2,920 meters) Upper Jurassic fine-grained sandstone is interbedded with gray and red-brown shale and minor limestone. Oolitic limestone from 9,580 to 10,350 feet (2,133 to 3,155 meters) contains very coarse to fine oolites cemented by micrite. Still in Upper Jurassic from 10,350 to 11,200 feet (3,155 to 3,414 meters) the well penetrated argillaceous micrite along with shales.

Straddling the Upper Jurassic-Middle Jurassic boundary at 11,800 feet (3,596 meters), the section from 11,200 to 13,350 feet (3,414 to 4,069 meters) consists of micritic limestone with some anhydritic and oolitic zones interbedded with anhydrite, fine dolomite, and minor thin shale. Below 11,800 feet (3,596 meters) the age of the section ranges from Middle Jurassic to Triassic, but the time subdivisions have not been resolved yet. Limestone, dolomite, and anhydrite comprise the section from 13,350 to 18,500 feet (4,069 to 5,639 meters). Between 18,500 and 19,150 feet (5,639 and 5,837 meters) fine-grained sandstone ranges to calcareous siltstone and silty limestone.

From 19,150 to 21,800 feet (5,837 to 6,644 meters) limestone occurs interbedded with dolomite and anhydrite. Salt occurs from 21,800 feet (6,644 meters) to total depth of 21,874 feet (6,667 meters).

The COST G-2 well can be divided into five geochemical zones with additional subzones. The upper two zones, down to 10,500 feet (3,200 meters), have high organic content but are thermally immature. A subzone between 5,000 and 5,800 feet (1,524 and 1,768 meters) yielded high amounts of methane and could represent a prospective gas source. Maturation increases in the deeper, predominantly carbonate section so that the two deepest zones, below approximately 14,000 feet (4,267 meters), are in the initial stages of oil generation and represent a potentially favorable oil source sequence. In fact, excellent oil-like hydrocarbons have been detected in most samples from these zones. The kerogen type in the lowest subzone, 19,000 to 21,800 feet (5,791 to 6,644 meters), is more terrestrial and thus more gas prone. Numerous minor gas shows were detected in sidewall cores taken in the well between 4,000 and 10,000 feet (1,219 to 3,048 meters). An average geothermal gradient of 1.40°F per 100 feet was measured in the well. (Amato and Simonis, 1980).

C. Mid-Atlantic COST No. B-2 Well

The COST No. B-2 well was drilled at a cost of approximately $8 million in the Baltimore Canyon Trough, 91 miles (146 kilometers) east of Atlantic City, New Jersey, to gain geological, geophysical, and engineering data before OCS Sale No. 40. The well bottomed at a total depth of 16,043 feet (4,890 meters) in Upper Jurassic rocks and was plugged and abandoned. This was the first deep stratigraphic test drilled on the U.S. Atlantic OCS and has provided unique and valuable data. Ocean Production was the operator for 31 total participants.

The well was spud on December 14, 1975, and plugged and abandoned on March 28, 1976. Well ditch cuttings, 4 conventional cores, and 822 sidewall cores were analyzed along with electric logs before abandonment. No liquid oil shows were reported in the cores or cuttings, and only insignificant amounts of methane gas were noted on the mud log. There was no indication that the well encountered any zone containing hydrocarbons.

The shallowest strata penetrated by the well were a 222-foot (68 meter) section below the sea bottom and an underlying 300-foot (91 meter) interval of coarse sand, shell fragments, and glauconite, which was barren of fossils and could not be dated. This section was probably a combination of nonmarine or very shallow marine Pleistocene, Pliocene, and uppermost Miocene sediments. The next interval between 910 and 3,596 feet (277 and 1,096 meters) was dated as Miocene, and a middle to outer shelf environment was indicated. Coarse sand continued to 2,600 feet (792 meters), underlain by shale and soft mudstone to 3,050 feet (930 meters), coarse sand to 3,500 feet (1,067 meters), and shale to 3,600 feet (1,097 meters). Oligocene rocks were encountered between 3,596 and 4,082 feet (1,096 and 1,244 meters) and included shales and claystone deposited in a deep-water environment. Eocene sediment occurred from 4,082 to 4,964 feet (1,244 to 1,513 meters) and was predominantly buff, dense, argillaceous limestone with lesser amounts of claystone. A thin sequence of Paleocene rocks occurred between 4,964 and 5,000 feet (1,513 and 1,524 meters) consisting of tan argillaceous limestone and claystone. Eocene and Paleocene sediments were also deposited in deep water.

Cretaceous strata were first encountered at 5,000 feet (1,524 meters), and the well penetrated Cretaceous rocks to 11,800 feet (3,596 meters). Upper Cretaceous strata occurred between 5,000 and 8,130 feet (1,524 and 2,478 meters). They included a porous sandstone between 5,000 and 5,200 feet (1,524 and 1,584 meters) and shale, clay, and minor amounts of chalky limestone from 5,200 to 5,800 feet (1,584 to 1,768 meters) that were deposited in deep water. Coarse- to medium-grained sandstone with lesser amounts of shale, thin limestone, and lignite deposited in shallow to moderately deep water was encountered from 5,800 to 6,850 feet (1,768 to 2,088 meters). A mixed sequence of shales with thin beds of dolomite, limestone, and fine-grained sandstone deposited in middle shelf or upper slope environments was found between 6,850 and 8,130 feet (2,088 and 2,478 meters).

Lower Cretaceous rocks extended to 11,800 feet (3,596 meters) and included a thick series of coarse- to medium-grained calcareous sandstone with thin interbeds of shale, coal, limestone, and dolomite in the interval between 8,130 and 10,500 feet (2,478 and 3,200 meters). This section contained abundant reservoir-quality sandstone deposited in shallow marine water and was sampled by conventional cores at 8,238 feet (2,510 meters) and at 9,280 feet (2,828 meters). The interval between 10,500 and 11,500 feet (3,200 and 3,505 meters) consisted of fine-grained sandstone with generally low porosity and shales with interbedded coal and lignite. Paleoenvironments alternated in this section from nonmarine to shallow marine. Paleontological horizons were revised after the release of the open-file report on this well. The top of the Jurassic section was identified at 11,800 feet (3,596 meters). The Jurassic section from 11,800 feet (3,596 meters) to total depth of 16,043 feet (4,890 meters) was a predominantly nonmarine sequence of moderately porous to nonporous, fine- to coarse-grained sandstone and variegated shales with minor amounts of coal and lignite.

Excellent reservoir-quality rocks appear to be present in the Cretaceous and Upper Jurassic section to a depth of 12,100 feet (3,688 meters).

Organic-rich, fine-grained potential source rocks were found between 9,400 and 13,900 feet (2,865 and 4,237 meters) by detailed geochemical analysis. Studies of thermal maturity indicated that if these rocks were exposed to greater temperature alteration they could generate large quantities of gas and related liquids. (Smith et al., 1976).

D. Mid-Atlantic COST No. B-3 Well

The COST No. B-3, drilled in 2,686 feet (819 meters) of water, at a cost of approximately $13 million, is the first deep well to penetrate the U.S. Atlantic slope. The well was drilled by Chevron USA Inc. with 10 other expense-sharing companies to a total depth of 15,820 feet (4,822 meters) in the Baltimore Canyon Trough area, about 93 statute miles (150 kilometers) southeast of Atlantic City, New Jersey. Drilled by the dynamically positioned drillship Ben Ocean Lancer, the well was spud on October 9, 1978, and completed on January 25, 1979. Geological and engineering data obtained from this deep stratigraphic test were used by participating companies and the Federal Government for evaluating the petroleum potential, as well as possible drilling problems in deep-water areas in preparation for Lease Sale No. 49, held on February 28, 1979.

Geophysical logs were analyzed along with mud logs and pressure analysis logs were plotted during drilling and four wireline formation tests, which were made near the bottom of the well. An average temperature gradient of 1.36°F per 100 feet was determined from geophysical log thermometer readings.

Four conventional cores, 1,466 sidewall cores, and ditch cuttings were obtained from the well. The COST No. B-3 penetrated Pleistocene, Pliocene, Miocene, Cretaceous and Upper Jurassic sediments.

The stratigraphic sequence penetrated by the B-3 is divided into four major lithologic groups. Section I occurs from 3,790 to

6,080 feet (1,155 to 1,853 meters) and consists of Tertiary (Miocene) calcareous mudstone, claystone, and minor amounts of argillaceous limestone and siltstone deposited in middle shelf to upper slope environments. Section II, from 6,080 to 8,200 feet (1,853 to 2,499 meters), includes mudstone, siltstone, and minor sandstone of Late Cretaceous age deposited in a prodelta to middle shelf environment. Section III, from 8,200 to 12,400 feet (2,499 to 3,779 meters), contains sandstone, shale, and minor carbonate rocks of Early and Late Cretaceous age; these strata were laid down in environments ranging from outer shelf to deltas and river channels. The deepest section, IV, from 12,400 to 15,820 feet (3,779 to 4,820 meters), comprises sandstone, limestone, and shale of Late Jurassic age deposited in nearshore tidal flat to outer shelf environments.

A total of 1,625 feet (495 meters) of porous sandstones of petroleum reservoir quality were logged in the well from geophysical log analysis. Porosity diminished rapidly below 12,000 feet (3,657 meters) where the rocks are predominantly limestone and shale; porosity of the sandstone in this section is reduced mainly by cementation and pressure solution. The section from 8,000 to 12,000 feet (2,438 to 3,657 meters) contains the best combination of potential reservoir rocks and sealing beds.

The petroleum potential of the strata penetrated by the well ranges from poor in the upper part of the section to good in the lowest part. The Tertiary and part of the Upper Cretaceous section down to 8,200 feet (2,499 meters) contains abundant reservoir rocks and hydrogen-rich organic matter, but lacks thermal maturation. The remainder of the Upper Cretaceous and part of the Lower Cretaceous section between 8,200 and 11,630 feet (2,499 and 3,545 meters) includes potential reservoir rocks; however, geochemical data indicate that kerogen in this interval is of terrestrial origin and has not quite reached the required maturity for petroleum generation. The Lower Cretaceous and Upper Jurassic section from 11,630 feet (3,545 meters) to total depth consists mainly of limestone, sandstone, and shale and includes potential reservoir rocks. This section is thermally mature, and except between 13,000 and 14,000 feet (3,962 and 4,267 meters), contains sufficient organic matter to have generated dry gas, with some likelihood of oil above 13,000 feet (3,962 meters). The best potential for hydrocarbons occurs below 14,000 feet (4,267 meters), although vertical migration of gas into reservoirs above this level may have occurred.

During drilling of the B-3 well, a show of gas was encountered in the interval from 15,744 to 15,752 feet (4,799 to 4,801 meters). Mud log gas readings and electric log analysis indicated the presence of 8 feet (2 meters) of gas-bearing sandstone averaging 12 percent porosity and a water saturation of 32 percent. Two formation tests in this zone recovered small amounts of gas; and the show, judged to be significant, was publicly announced, in keeping with regulations. The gas was probably contained in a small stratigraphic trap not discernible on seismic lines over the drill site. (Amato and Simonis, 1979).

E. South Atlantic COST No. GE-1 Well

Ocean Production Company, acting as the operator for a group of 25 oil companies, drilled the COST No. GE-1 well to obtain scientific data about the geology and potential petroleum resources of the South Atlantic Outer Continental Shelf. The well was drilled to a total depth of 13,254 feet (4,040 meters) between February 22 and May 31, 1977, by the drill barge Ocean Star. The drill site was approximately 74 nautical miles (119 kilometers) east of Jacksonville, Florida, in a sedimentary basin known as the Southeast Georgia Embayment. The well provided much useful geological information to aid in the evaluation of tracts offered in OCS Lease Sale No. 43.

The COST No. GE-1 well was drilled in 136 feet (41 meters) of water at a total cost of $7.5 million. Electric logs, a mud log and a seismic velocity log, 6 drill stem tests, 15 coventional cores, numerous sidewall cores, and ditch cutting samples were obtained and analyzed.

The well penetrated a Pliocene through Oligocene interval from 390 feet (119 meters), where sampling started, to 1,000 feet (305 meters) consisting of unconsolidated sand, gravel and calcareous mudstone with abundant shell fragments and microfossils. The rock strata from 1,000 to 3,570 feet (305 to 1,088 meters) are of predominantly Eocene age and include crystalline to argillaceous limestone, brown dense dolomite, and chert.

The uppermost Cretaceous interval from 3,570 to 4,350 feet (1,088 to 1,326 meters) is a dominantly marine unit of light-to dark-gray, calcareous, partly cherty claystone and shale. The interval between 4,350 and 5,320 feet (1,326 and 1,621 meters) is composed largely of calcareous mudstone ranging to clayey limestone. The interval between 5,320 and 5,730 feet (1,621 and 1,746 meters) is mainly a calcareous shale.

The section between 5,730 and 11,050 feet (1,746 and 3,368 meters) is poorly dated but is probably of Early Cretaceous age, except possibly for the lowest few hundred feet. A sandstone, approximately 100 feet (30 meters) thick, below 5,730 feet (1,746 meters) is underlain by a thick carbonate section consisting of shallow marine limestone, in part oolitic, interbedded with thin anhydrite and minor dolomite down to 7,090 feet (2,161 meters). Between 7,090 and 10,700 feet (2,161 and 3,261 meters) the section consists of shale, fine to medium sandstone and minor anhydrite and dolomite, which were probably deposited in or near a sebkha-type environment. The interval from 10,700 feet to 11,050 feet (3,261 to 3,368 meters) is composed of rocks interpreted as Mesozoic conglomerates consisting of quartzite clasts. Based on K-Ar and Rb-Sr age determinations the rocks below 11,050 feet (3,368 meters are considered to be of early Paleozoic (Devonian) age. Above 13,000 feet (3,962 meters) they are highly indurated to weakly metamorphosed shales, dolomites, and quartzites. Below 13,000 feet (3,962 meters) to total depth at 13,254 feet (4,040 meters) the rocks have been identified as green schist-facies metamorphics intruded by hypabyssal igneous rocks.

The section from 5,750 to 7,000 feet (1,753 to 2,133 meters) contains the best combination of potential reservoir rocks and sealing beds.

Geochemically, the section is thermally immature and organically lean, to a depth of 2,800 feet (853 meters), and shows little potential for hydrocarbon generation. From 2,800 to 5,800 feet (853 to 1,768 meters), it is also immature but contains abundant algal-amorphous sapropellic kerogen, which is an excellent oil source material. The section from 5,800 to 9,200 feet (1,768 to 2,804 meters) contains small amounts of organic carbon, but is also thermally immature. The remainder of the hole below 9,200 feet (2,804 meters) is mature enough for petroleum generation but is barren of source rocks. The average temperature gradient is 0.85°F per 100 feet. (Amato and Bebout, 1978).

F. **Central Gulf of Mexico COST No. 1 Well**

A consortium of nine oil companies led by Marathon, as operator, drilled at an estimated cost of $405,000, the Central Gulf of Mexico COST No. 1 well approximately 45 miles (72 kilometers) southeast of Breton Sound in 605 feet (184 meters) of water, on Viosca Knoll Block 774. The well was spud on August 27, 1989, drilled to total subsurface depth of 852.7 feet (284 meters) and plugged and abandoned on September 4, 1989. The main objective of the COST No. 1 well was to study the effect of sea level changes on the continental shelf slope.

The COST No. 1 well was cored to 806 feet (246 meters) subsurface, using a hydraulic piston coring wireline technique. A summary of lithological description by the operator indicates that the well penetrated sedimentary section consisting of layers of mostly clays varying from olive green, gray, to dark colors with occasional sandy silt, fine sands, and shell fragments pockets. Gassy sediments were more commonly noted in the lower part of the section. The Louisiana State University Geoscience Department will conduct organic geochemical and isotopic tests and paleontological analyses. (MMS Gulf of Mexico Region, Written Communication 1990).

G. **Western Gulf of Mexico COST No. 1 Well**

The COST No. 1 deep stratigraphic test offshore south Texas was spud on August 25, 1974, drilled to a total depth of 15,763 feet (4,804 meters), and abandoned on November 13, 1974. A consortium of 32 oil companies led by Phillips as the operator drilled the well 40 miles (64 kilometers) east of South Padre Island, Texas, in 140 feet (43 meters) of water. The well reached total depth in Lower Miocene sediments. Total cost was approximately $3 million.

Although the stratigraphic column penetrated in the subject well is similar in some respects to that of Louisiana, no potential reservoir rocks were detected in the COST No. 1 well. The gross lithology in the well is essentially the same from top to bottom. Massive shale is infrequently interrupted by very thin, limey sections and silty-sand streaks with no visible reservoir potential. The sonic log interpretations indicate that the clastic sediments penetrated in the subject well are essentially undercompacted and highly porous. The porosity in these shale sequences ranges from 30 to 43 percent. The thin, limey sections are dense, crystalline and partially dolomitized.

The Pleistocene section ranges from 450 to 2,550 feet (137 to 777 meters). The Lower Pleistocene sediments are composed of a massive shale with occasional silty sand streaks. The younger Pleistocene sediments contain a sedimentary sequence of alternating sands and shale.

Although a few sand sections occur in the Upper Pleistocene, these sediments are not considered to be prospective. However, the Pleistocene deposits were controlled by the sea level, which fluctuated from low stages during glacial periods to high stages during interglacial periods. Consequently, stratigraphic and lithologic conditions may vary laterally, and some sediments could be prospective in localized areas in the downdip position.

The Pliocene section ranges from 2,550 to 4,860 feet (777 to 1,481 meters). These rocks for the most part are lacking necessary sandstone reservoir characteristics. The Pliocene section penetrated by the COST No. 1 is approximately 2,310 feet (704 meters) thick, and the entire sedimentary sequence consists of dark-grey shale with no reservoir potentials.

The Miocene section is between 4,860 (1,481 meters) and the total depth of the well at 15,763 feet (4,804 meters). The Miocene rocks penetrated in the well are approximately 10,840 feet (3,304 meters) thick, and the entire section is composed of a massive shale infrequently interrupted by very thin, limey sections and silty-sand streaks with no potential reservoir rock.

The COST No. 1 well essentially confirms the lateral change in lithologic character, which can be seen in the Miocene and Pliocene sedimentary sections when traced from onshore to State waters in the South Padre Island area.

The absence of reservoir sand characteristics in the Miocene-Pliocene sediments penetrated in the COST No. 1 well probably reflects that very little coarse material was available to this gradually subsiding area during Miocene and Pliocene time. The Texas Mio-Pliocene rivers were probably not big enough to build large deltas. Much of the sand brought down by these rivers was probably deposited on beaches and as bars in nearshore transitional environments. Only fine sediments were apparently transported to the outer-shelf areas in the Rio Grande Embayment. (Khan et al., 1975a).

H. Western Gulf of Mexico COST No. 2 Well

The COST No. 2 well was spud on December 6, 1974, drilled to a total depth of 13,000 feet (3,962 meters), and abandoned on February 19, 1975. A consortium of 32 oil companies led by Superior as the operator drilled the well 42 miles (68 kilometers) east of North Padre Island, Texas, in 240 feet (73 meters) of water. The well reached total depth in lower Miocene sediments. Total cost was approximately $3 million.

The stratigraphic column penetrated in the subject well is similar in some respects to that of the COST No. 1 well in South Padre Island, East Addition. With the exception of some Holocene sediments, the stratigraphic section penetrated in the COST No. 2 well consists of Pleistocene, Pliocene, and Miocene rocks. Although the gross lithology of these rocks is characterized by a clastic sequence of alternating shale with fine-grain sand sections, very few sands were encountered in the Miocene below 5,500 feet (1,676 meters). The upper Miocene and younger sedimentary sequences appear to have 10 to 15 percent sand.

The massive shale of the lower Miocene is infrequently interrupted by very thin limey and fine-grained sand sections with no apparent reservoir potentials. The sonic log interpretations indicate that the shaley sedimentary sections down to 9,300 feet (2,835 meters) in the COST No. 2 well are relatively under-compacted and highly porous. Below 10,310 feet (3,142 meters) the sediments appear to be highly compacted.

The Pleistocene section ranges from 780 to 1,550 feet (238 to 472 meters). The reservoir rock characteristics of the Pleistocene sedimentary sequence penetrated in the COST No. 2 well are very similar to those of the COST No. 1 well. The lower Pleistocene rocks are composed primarily of shale with silty sand sections. The upper Pleistocene sediments consist of a sequence of alternating shaley sand and shale.

The Pliocene section ranges from 1,550 to 2,180 feet (472 to 664 meters). The Western Gulf stratigraphic tests (COST No. 1 and COST No. 2) probably confirm that these rocks for the most part are lacking necessary sandstone reservoir characteristics in the south Texas OCS. The Pliocene section penetrated in the COST No. 2 well is only 630 feet (192 meters) thick, and the sedimentary sequence is composed of shale with some silty sand sections with poor reservoir characteristics.

The Miocene section is encountered from 2,180 feet (664 meters) to total depth at 13,000 feet (3,962 meters). The Miocene section penetrated in the COST No. 2 well is, for the most part, composed of shale. The sand sections in the upper Miocene do have reservoir rock qualities. However, the lower Miocene and early upper Miocene rocks penetrated in the COST No. 2 well show relatively poor reservoir characteristics though good sand conditions appear to exist landward of the well.

The Miocene-Pliocene stratigraphic sections penetrated in the COST No. 2 well are relatively thinner and structurally high compared to that of the COST No. 1 well in the South Padre Island Area. This difference may be a reflection of a greater subsidence of the South Padre Island area relative to Mustang Island during Miocene-Pliocene time.

The results from the two Western Gulf deep stratigraphic tests (COST No. 1 and No. 2) offshore south Texas show that the sedimentary rocks penetrated in these wells are essentially lacking overall potential reservoir sand characteristics. In general, this absence may reflect that little coarse material (sand) was available to this gradually subsiding area during the late Tertiary and Quaternary Periods. Texas Mio-Pliocene rivers were probably not big enough to build large deltas, similiar to the Mississippi deltas offshore Louisiana. (Khan et al., 1975b).

I. Southern California OCS-CAL 75-70 No. 1 Well

The deep stratigraphic test OCS-CAL 75-70 No. 1 was spud on August 23, 1975, and completed on December 2, 1975, by Exploration Services Company, Inc. (ESC) for 18 total participants. It is located in the Outer Banks area of the southern California continental Borderland on the southeastern end of Cortes Bank in 348 feet (106 meters) of water. The well was drilled to a total depth of 10,920 feet (3,328 meters) into the Upper Cretaceous section and abandoned. Total cost was approximately $3 million.

The well furnished important data on the stratigraphy and petroleum potential of this part of the Borderland. The section represents an apparent continuous record of marine sedimentation from the Upper Cretaceous into the middle Miocene. Basement was not reached but is inferred from magnetometer studies to be at 12,000 + feet (3,657 + meters).

The penetrated section includes 1,905 ± feet (581 ± meters) of middle and early Miocene age rocks, 567 feet (173 meters) of basalt flows of possible Oligocene age, 1,340 ± feet (408 ± meters) of Oligocene, 1,950 feet (594 meters) of Eocene, 850 feet (259 meters) of Paleocene, and 3,930 feet (1,198 meters) of Late Cretaceous age rocks. A section of middle Upper Cretaceous is missing (unconformity) within the Upper Cretaceous.

The sequence of Eocene and Oligocene sedimentary lithofacies in the well is similar to approximate age-equivalent rocks in the Point Conception area of the western Santa Ynez Mountains. The Sespe Formation, which ranges in age from late Eocene to early Miocene and is a widespread continental deposit that exists in the northern Channel Islands and onshore, is absent in the well. Likewise, the middle Miocene San Onofre Breccia, which is present in the northern Channel Islands, Santa Monica Bay area and onshore north of Oceanside, is not present, and no detritus of Catalina Schist was found within the section penetrated by the well.

No liquid hydrocarbon shows were reported in cores, sidewall samples, or ditch cuttings, and only methane gas of an insignificant amount was noted on the mud log. Thin vein-like solid hydrocarbon material exists in a 6-inch contorted sandy siltstone interval at the top of a graded turbidite sandstone bed at 8,734 feet (2,662 meters). This insoluble material has been analyzed as solid bitumen.

Petroleum source rock studies on samples from the well extend the potentially good to excellent source rocks from the Miocene down into the middle to upper Eocene. Lower and lower-middle Eocene, Paleocene, and Cretaceous rocks have low organic carbon content and are considered poor potential source rock for the generation of petroleum.

The organically rich upper Eocene and younger rocks of similar high organic content should be potentially good to excellent source rocks for petroleum if buried to depths of 10,000 feet (3,048 meters) or more.

Porous sandstone of potential reservoir quality exists in the well from the middle Miocene into the Upper Cretaceous section. There is approximately 1,280 feet (390 meters) of sandstone with an average porosity of 32 percent in the middle Miocene section, and approximately 850 feet (259 meters) of 30 percent porosity sandstone of Oligocene age. In the Eocene to Upper Cretaceous section there is a net sand thickness of approximately 839 feet (258 meters) above the unconformity at 7,965 feet (2,428 meters). However, this sandstone occurs over several widely spaced intervals and the sandstone beds are thin. Although the sandstone is well to very well sorted, with moderate porosities ranging from 13 to 17 percent, the mean permeability is less than 10 millidarcies. The Cretaceous sandstone below this unconformity is not considered prospective as an oil reservoir and is a poor prospect as a possible gas reservoir because of the very low porosities. (Paul et al., 1976).

J. Point Conception CAL 78-164 No. 1 Well

The Point Conception well, spud on October 8, 1978, is designated the OCS-CAL 78-164 No. 1. This well was drilled about 10 miles (16 kilometers) southeast of Point Arguello in 1,428 feet (431 meters) of water. The well was drilled to a total depth of 10,571 feet (3,222 meters) and was plugged and abandoned on December 18, 1978. This is the second deep stratigraphic test that has been drilled in offshore California, and like the first well, this one was drilled by ESC, but for 14 total participants. Total cost was approximately $4.5 million.

Based on analysis of fossils, the section is Cenozoic in age down to a drilled depth of about 10,000 feet (3,048 meters). At this depth an unconformity is inferred to exist between Miocene and lower Cretaceous or uppermost Jurassic strata.

Significant shows of oil and gas occurred between 2,900 and 5,800 feet (884 and 1,768 meters). Formal announcement of these shows was made in November 1978 as required by 30 CFR 251 regulations. The sediment down to a depth of about 4,400 feet (1,341 meters) is mainly mudstone, siltstone, and sandstone. Siliceous mudstone is abundant from 4,400 to 5,450 feet (1,341 to 1,661 meters). From 5,450 to 7,400 feet (1,661 to 2,255 meters) porcellanite, chert, and minor amounts of dolomite dominate the section. Siltstone, mudstone, sandstone, and conglomerate occur in the interval from 7,400 to 9,735 feet (2,255 to 2,967 meters). From 9,735 feet (2,967 meters) to the base of the hole the section consists of sheared and polished mudstone and siltstone.

By analogy with several outcrop areas on land, the well section most closely resembles sediment exposed in the Tranquillon Mountain area. There, lower Miocene beds overlap

Oligocene, Eocene, and Upper Cretaceous formations onto Lower(?) Cretaceous strata.

The present geothermal gradient in the Point Conception well is 3.6°F per 100 feet. This is an exceptionally high gradient and is comparable to temperature gradients from the largest oil fields in the Santa Maria Basin and the Wilmington oil field in the Los Angeles Basin.

Organic geochemical studies indicate the organic matter from the Point Conception well is dominantly of a type that has excellent oil-generating capacity. This and other geochemical data suggest that the organic matter in these rocks may yield significant amounts of hydrocarbons at early stages of thermochemical transformation.

Log calculations indicate that the section down to 5,400 feet (1,646 meters) is strongly undercompacted, with mean porosity values in the range from 44.4 to 33.8 percent. Strata between 5,400 and 9,450 feet (1,646 and 2,880 meters) have calculated density log porosity values from 29.8 to 9.3 percent. Porosity values calculated from the density log through the interval 9,450 to 9,979 feet (2,880 to 3,041 meters) have a mean value of 10 percent. Burial consolidation and cementation by carbonate minerals may account for much of the progressive loss of porosity with increasing depth.

Petroleum in some California oil fields, both onshore and offshore, exists in sandstone reservoirs with intergranular porosity. However, in many fields, interconnected fractures in diagenetically altered siliceous (Monterey Formation) "shale" form the reservoirs. Two such places are the nearby Santa Maria Basin onshore and the Santa Barbara Channel offshore. Fracture porosity in purely diagenetic or structural-diagenetic combination traps may prove to be a key element in the discovery of oil in the area surrounding this well. (Cook, 1979).

K. Northern Gulf of Alaska COST No. 1 Well

The Northern Gulf of Alaska COST No. 1 well was drilled by ARCO on OCS Tract 196 (Block 1382N-76E), OCS map No. 7-1 (Icy Bay) 29 miles (46 kilometers) southwest of Cape Yakataga, Alaska, for a total cost of approximately $12 million. It was spud on July 22, 1975, and completed on October 10, 1975, in 570 feet (174 meters) of water. Twenty-six companies shared the cost and the well was permitted to a depth of 16,500 feet (5,029 meters). However, the well was plugged and abandoned at a depth of 5,150 feet (1,570 meters) because various drilling and weather problems had so slowed progress that it was unlikely that the objective total depth could be reached before to OCS Sale No. 39, Gulf of Alaska.

The well was intended to reach a total measured depth of 16,500 feet (5,029 meters) so as to penetrate the rocks of primary interest, the lower part of the Yakataga Formation, an interval that is below 10,000 feet (3,048 meters) in the test area. The entire interval that was logged and sampled consisted of marine and glaciomarine clastic rocks in the upper part of the Yakataga Formation and of probable middle to late Pleistocene age. Because the total depth reached was only 5,150 feet (1,570 meters), the COST well provided no lithologic information concerning potentially productive horizons.

Sample analysis indicates that sandstones are not of reservoir quality due to the presence of interstitial silt and clay and carbonate cement. This is further indicated by well logs that showed high "shaliness" in all the sandy intervals. The logs do not indicate the presence of any hydrocarbons. An organic geochemical study of samples from the well indicates that the entire interval penetrated has a thermally immature source character and probably has not generated any liquid hydrocarbons. (Bolm et al., 1976).

L. **Lower Cook Inlet COST No. 1 Well**

The Lower Cook Inlet COST No. 1 well was spud on June 10, 1977, and completed on September 24, 1977, to a total depth of 12,387 feet (3,775 meters). The well is located on Block 489, Map No. 5-2 (Seldovia), 20 miles (32 kilometers) from shore in a water depth of 216 feet (66 meters). Nineteen companies shared the cost of approximately $11 million with ARCO serving as operator.

Analysis of data from the well has led to the following conclusions about the strata penetrated by the well:

1. The well penetrated strata of Early Tertiary, Late Cretaceous, Early Cretaceous, and Late Jurassic ages.

2. Moderate amounts of sandstone reservoir rocks were encountered in the Tertiary and Cretaceous strata.

3. The reservoir sandstones encountered have been diagenetically altered to varying degrees by the authigenic growth of clays and zeolites. The alteration of the sandstones has resulted in reduction of their permeability and has almost obliterated any original porosity and permeability in the rocks below 6,850 feet (2,088 meters) of depth in the well.

4. The Tertiary and Upper Cretaceous rocks penetrated by the well exhibit good methane gas source characteristics and poor oil source characteristics. The Lower Cretaceous and Upper Jurassic rocks exhibit poor to fair methane gas source characteristics and poor oil source characteristics. The thermal maturity of the rocks increases from moderately immature at shallow depths to mature at total depth. (Wills et al., 1978).

M. **Kodiak Deep Stratigraphic Test Wells**

Six deep stratigraphic test wells were drilled on the Kodiak shelf in support of proposed Lease Sale No. 46. Three were drilled in 1976 and three in 1977. The first series of wells, the Kodiak Shelf Stratigraphic Test (KSST) Program, consisted of the KSST No. 1, KSST No. 2, and KSST No. 4A wells, and was drilled by Exploration Services Company, Inc. (ESCI), for 10 participants each. They were drilled to shallow depths and obtained relatively limited data. These data were made available for public inspection as required by 30 CFR 251.14, but no formal report was issued at the time. The second series of Kodiak shelf wells, the Kodiak Shelf Stratigraphic Drilling (KSSD) Program, consisted of the KSSD No. 1, KSSD No. 2, and KSSD No. 3 wells, and was drilled in 1977 by Sun Oil Company. These wells were drilled to much greater depths and acquired far more data. The last well was completed in October 1977. The MMS interpretations of the data from all six wells were released in one report (see Turner et al., 1987). Total costs were not available.

The KSST wells were drilled between 51 and 88 miles (82 and 142 kilometers) offshore in water depths between 162 and 307 feet (49 and 94 meters). Total depth for the KSST No. 1 well was 4,225 feet (1,288 meters), for the KSST No. 2 well was 4,307 feet (1,313 meters), and for the KSST No. 4A well was 1,391 feet (424 meters).

The KSSD wells were drilled between 54 and 121 miles (87 and 195 kilometers) offshore in water depths between 280 and 600 feet (85 and 183 meters). The total depth for the KSSD No. 1, No. 2, and No. 3 wells were 8,517 feet (2,596 meters), 10,460 feet (3,188 meters) and 9,357 feet (2,851 meters), respectively.

The KSSD No. 1 and 2 had 14 participants, whereas the No. 3 had 6.

The stratigraphic section penetrated by the six Kodiak shelf COST wells consists of sedimentary rocks derived from volcanic, metamorphic, plutonic, and sedimentary source terranes. The sedimentary section does not contain good petroleum reservoir or source rocks. Extremely fine grain size, abundant clay, poor sorting, and the formation of authigenic minerals have all contributed to creating low permeabilities.

Wireline well log data from the six Kodiak shelf COST wells were interpreted to determine the lithology, reservoir characteristics, and stratigraphy of the sedimentary rocks that underlie the Kodiak shelf. Six conventional cores were taken from the KSSD No. 1 well, two from the KSSD No. 2 well, and four from the KSSD No. 3 well. No conventional cores were taken from the three KSST wells.

The stratigraphic section penetrated by the three shallow Kodiak COST wells (KSST Nos. 1, 2, and 4A) consists of relatively undeformed Plio-Pleistocene glaciomarine sediments that mantle the Kodiak shelf. The three deep COST wells (KSSD Nos. 1, 2, and 3) penetrated Miocene and Eocene sedimentary rocks, in addition to the Plio-Pleistocene strata. No Oligocene age strata were identified by any of the Kodiak COST wells. The bulk of the Plio-Pleistocene sediment, and perhaps the Miocene sediment as well, appears to represent glacial detritus that has been reworked by marine processes, although airborne volcanic ejecta and erosion of sedimentary bedrock from submarine outcrops along submarine structural highs probably also supplied significant amounts of sediment. The Plio-Pleistocene to Miocene section is largely equivalent in age to the shallow marine shelf strata of the Tugidak (Upper Pliocene to Pleistocene) and Narrow Cape (lower and middle Miocene) Formations that crop out on Tugidak and Chirikof Islands.

The Paleogene section penetrated by the KSSD wells consists of structurally deformed Eocene strata. These rocks consist of shale, siltstone, and sandstone that are highly indurated except where overpressured conditions exist. The Eocene sediments penetrated in the KSSD wells appear to represent the Kodiak shelf equivalents of the Sitkalidak Formation, which is exposed on Kodiak Island and vicinity.

Sediments sampled by these six stratigraphic test wells contain mostly humic to woody kerogen, which is generally considered to be gas prone. In general, the organic content of the sedimentary sections penetrated by the wells on the Kodiak shelf is low, and insufficient to generate significant amounts of hydrocarbons.

The three deep wells (KSSD) sampled two geopressure provinces, a central and southwestern province sampled by the KSSD Nos. 1 and 3 wells, and a northeastern province sampled by the KSSD No. 2 well. The KSSD No. 2 well differs from the other wells on the Kodiak shelf in two ways: (1) it alone encountered abnormal formation pressure, and (2) the basement complex in the KSSD No. 2 well is undercompacted and appears to be homoclinally tilted northward, whereas coeval strata in wells to the southwest are steeply dipping, highly deformed, and overconsolidated. (Turner et al., 1987).

N. North Aleutian Shelf COST No. 1 Well

The ARCO North Aleutian Shelf COST No. 1 well, located approximately 200 miles (322 kilometers) northeast of Dutch Harbor, Alaska, was drilled to a depth of 17,155 feet (5,229 meters). The water depth at the well site was 285 feet (87 meters). Drilling operations began on

September 8, 1982, and the well was abandoned on January 14, 1983. There were 18 original participants. Total costs are estimated to be approximately $30 million.

Although seafloor instability and gas-charged sediments are major geologic hazards in the North Aleutian Basin, the well was drilled in an area not affected by these potential impediments. The area is also subject to severe seismicity. Wireline log data clearly identify a potentially dangerous zone of abnormal formation pore pressure from 11,200 to 16,300 feet (3,414 to 4,968 meters).

Nineteen conventional cores, 442 sidewall cores, and well cuttings collected at 30-foot intervals were analyzed. The stratigraphic section was divided into lithostratigraphic zones on the basis of lithology and well log characteristics. Five seismic sequences were delineated in the North Aleutian Basin, each representing a conformable unit of strata bounded by unconformities or their correlative conformities. The well penetrated Pleistocene mud, clay, and sandy diatomaceous ooze from 1,380 to 1,560 feet (420 to 475 meters); Pliocene diatomaceous ooze and sandy mudstone from 1,560 to 2,670 feet (475 to 814 meters); clay-rich fine- to medium-grain Miocene sandstones from 2,670 to 4,870 feet (814 to 1,484 meters); Oligocene fine to coarse grain sandstones, conglomerate, shale, and claystone from 4,870 to 9,969 feet (1,484 to 3,038 meters); and Eocene fine to coarse grain volcaneogenic sandstones, mudstone, siltstone, conglomerate and coal from 9,969 to 17,150 feet (3,038 to 5,227 meters). Overall, the reservoir quality is modest, particularly below 10,400 feet (3,170 meters). However, some good potential reservoirs are present in Pliocene-Miocene and Oligocene strata.

Sufficient thermal maturity for the generation of crude oil exists below 12,700 feet (3,871 meters). The sediments penetrated by the well contained primarily type III, humic, gas-prone kerogen derived from terrestrial or nearshore sources. The best potential source rocks encountered in the well were between 16,020 and 16,800 feet (4,883 and 5,120 meters). Minor oil shows and thermogenic gas were encountered below 15,700 feet (4,785 meters). These shows were not judged to be significant. (Turner et al., 1988).

O. Norton Sound COST No. 1 Well

The ARCO Norton Sound COST No. 1 well was drilled to a measured depth of 14,683 feet (4,475 meters). The water depth was 90 feet (27 meters). The well site was approximately 54 miles (87 kilometers) south of Nome, Alaska. Drilling began on June 14, 1980, and was completed on September 16, 1980. The well was drilled from the drilling rig Dan Prince, for 17 participants at a total cost of approximately $14 million.

Twelve conventional cores, 533 sidewall cores, and many rotary drill bit cuttings were collected and analyzed. Logging runs were made at depths of 4,670 feet (1,423 meters), 12,175 feet (3,711 meters), and 14,683 feet (4,475 meters).

The strata penetrated by the Norton Sound COST No. 1 well were Pleistocene from 180 to 1,320 feet (55 to 402 meters); Pliocene from 1,320 to 2,639 feet (402 to 804 meters); Miocene from 2,639 to 4,740 feet (804 to 1,445 meters); and Oligocene from 4,740 to 9,690 feet (1,445 to 2,953 meters). The interval from 9,690 to 12,235 feet (2,953 to 3,729 meters) is Oligocene or older and is tentatively correlated with the middle to late Eocene section of the No. 2 well. The interval from 12,235 to 12,545 feet (3,729 to 3,824 meters) is considered correlative with the Eocene or older section of the No. 2 well. The well penetrated 2,138 feet (652 meters) of metasedimentary rocks similar to Precambrian (?) to Paleozoic slates exposed in the York Mountains on the Seward Peninsula. Deposition was mostly marine throughout except approximately 200 feet (61 meters) of transitional sediments in the upper part of the Oligocene section, and 310 feet (94 meters) of continental in the possible Eocene or older section.

Samples from the Pleistocene section were sporadic, of poor quality, and consisted primarily of unconsolidated shelly sand, lithic fragments, mud, and silt. The Pliocene section is predominantly a diatomaceous sandy mudstone with thin stringers that can be characterized as muddy diatomites. The Miocene section consists of sandy, diatomaceous mudstones similar to those of the Pliocene. The Oligocene section is characterized by thin, transitional deposits of sandstone, siltstone, and coal near the top of the unit, and marine mudstone, shale, and sandstone from 4,770 to 9,690 feet (1,454 to 2,953 meters). The older Oligocene section consists of mudstone and micaceous sandstone, often displaying graded bedding. The interval from 10,300 to 10,640 feet (3,139 to 3,243 meters) contains tabular igneous rocks that may represent either sills or flows. The possible Eocene or older section consists of interbedded sandstone, siltstone, shale, coal, and conglomerate. The section from 12,545 to 14,683 feet (3,824 to 4,475 meters) consists of slate and minor amounts of marble and is thought to be late Precambrian to Paleozoic in age.

Sandstone porosities of greater than 24 percent are restricted to depths of less than 6,000 feet (1,829 meters) in the No. 1 well. Pore reduction was the result of ductile grain deformation, authigenic mineral growth, and cementation.

Geochemical data indicate that the most common organic material present is type III humic gas-prone kerogen. Dry gas and wet gas condensate are the most likely hydrocarbons to be generated. Biogenic gas that may be present in near-surface sediments is no indication that thermógenic hydrocarbons have formed in significant quantities. The current oil window is between 9,500 and 12,500 feet (2,895 and 3,810 meters). Below 13,000 feet (3,962 meters) there is insufficient organic carbon to serve as a commerical hydrocarbon source. A thermal gradient of 2.01 to 2.44°F per 100 feet was calculated. (Turner et al., 1983, Norton COST No. 1).

P. Norton Sound COST No. 2 Well

The ARCO Norton Sound Cost No. 2 well was drilled to a measured depth of 14,889 feet (4,538 meters) 68 miles (109 kilometers) southwest of Nome. The water depth was 49 feet (15 meters). Drilling began on June 7, 1982, and was completed on August 27, 1982, for a cumulative cost of $32.2 million shared by 20 participants. Gas associated with coal beds was encountered from 12,212 to 12,717 feet (3,722 to 4,181 meters). The gas shows were deemed significant and a formal announcement was made in November 1982 in accordance with established regulations.

Thirteen conventional cores, 499 sidewall cores, and many well cutting samples were analyzed. Logging runs were made at depths of 4,700 feet (1,432 meters), 11,907 feet (3,629 meters), and 14,889 feet (4,538 meters).

Strata penetrated were Pleistocene in age from 450 to 1,320 feet (137 to 402 meters), Pliocene from 1,320 to 2,580 feet (402 to 786 meters), Miocene from 2,580 to 3,530 feet (786 to 1,076 meters), Oligocene from 3,530 to 10,280 feet (1,076 to 3,133 meters), Eocene from 10,280 to 12,700 feet (3,133 to 3,871 meters), Eocene or older from 12,700 to 14,460 feet (3,871 to 4,407 meters), and probable Paleozoic from 14,460 to 14,889 feet (4,407 to 4,538 meters).

Sample quality and recovery were poor in much of the Pleistocene section, and samples consisted of fine- to medium-grained, unconsolidated shelly sand with abundant lithic fragments and organic debris. The Pliocene section is characterized by siltstone, muddy sandstone, and diatomaceous mudstone. The Miocene section consists of diatomaceous mudstones, siltstone, and muddy sandstones. The Oligocene is coal-bearing over most of the section. The coal at the top of the section between 3,535 and 4,570 feet (1,077 and 1,393 meters) is continental, that below 6,300 feet (1,920 meters) is more estuarine and deltaic in aspect. Sandstone and siltstone are more common in the deeper marine intervals of 4,570 to 6,900 feet (1,393 to 2,103 meters) and 8,000 to 8,500 feet (2,438 to 2,591 meters). The Eocene section is transitional to inner neritic from 10,160 to 12,200 feet (3,097 to 3,718 meters) and is characterized by sandstone, siltstone, mudstone, and shale. Coal is present in many samples and may represent either caving or partings, as no coal beds were cored or seen on electric logs. The lower part of the interval between 12,200 and 12,700 feet (3,718 and 3,871 meters) contains coal, conglomerate, sandstone, mudstone, siltstone, and was deposited in a fluvial environment. The Eocene or older section between 12,700 and 14,460 feet (3,871 and 4,407 meters) contains interbedded sandstone, siltstone, mudstone, and abundant, thick coal beds. The interval from 14,460 to 14,889 feet (4,407 to 4,538 meters) contains quartzite, marble, and phyllite of probable Paleozoic age.

In general, on the basis of core data, sandstones with 12 percent or more porosity occur above 9,000 feet (2,743 meters) in the well.

A thermal gradient of 2.02°F per 100 feet was calculated for the section above 11,000 feet (3,353 meters); below this depth the mean gradient is 2.50°F/100 feet.

The organic matter is predominantly type III, humic, gas-prone kerogen. In addition to the gas shows between 12,212 and 13,717 feet (3,722 and 4,181 meters), minor occurrences of gas and liquid hydrocarbons were observed in samples obtained below 10,000 feet (3,048 meters). Methane, thought to be of biogenic origin, is present in a few sands above 3,000 feet (914 meters). (Turner et al., 1983, Norton COST No. 2).

Q. St. George Basin COST No. 1 Well

The ARCO St. George Basin COST No. 1 well was drilled to a measured depth of 13,771 feet (4,197 meters) at an approximate cost of $16.5 million. The water depth was 442 feet (135 meters). The well site was approximately 105 miles (169 kilometers) southeast of St. George Island, Alaska. Drilling began on July 2, 1976, and was completed on September 22, 1976. The well was drilled from the <u>Ocean Ranger</u>, a semisubmersible drilling unit, for 20 participants.

Thirteen conventional cores, 550 percussion sidewall cores, and well cuttings were collected at 30-foot intervals from 1,600 to 13,755 feet (488 to 4,192 meters). Logging runs were made at depths of 4,921 feet (1,500 meters) 10,217 feet (3,114 meters), 13,006 feet (3,964 meters), and 13,771 feet (4,197 meters).

Stratigraphic units encountered in the No. 1 well were Pliocene from 1,600 to 3,600 feet (488 to 1,097 meters), Miocene from 3,600 to 5,370 feet (1,097 to 1,637 meters), Oligocene from 5,370 to 8,410 feet (1,637 to 2,563 meters), and Eocene from 8,410 to 10,380 feet (2,563 to 3,164 meters). The age of the predominantly igneous section from

10,380 to 13,771 feet (3,164 to 4,197 meters) could not be determined. It is provisionally assigned an age of middle Eocene or older, but may be as old as Mesozoic.

The sedimentary section consists of interbedded sandstone, siltstone, mudstone, diatomaceous mudstone, and conglomerate. The sediment was derived predominantly from volcanic source terranes. The sediments consist of physically and chemically unstable materials easily deformed and altered. Permeabilities are lower than might be expected for given porosities. Porosity and permeability have been reduced by ductile grain deformation, cementation, and authigenesis.

Geochemical analyses indicate that the most common organic material present is type III, humic gas-prone kerogen. Average total organic carbon values in the well are low (0.5 percent) and the maximum value was only 0.74 percent. Sufficient maturity for gas generation was not attained in the sedimentary section penetrated. There is no evidence of crude oil or oil-associated gases. The calculated geothermal gradient is 1.95°F per 100 feet. (Turner et al., 1984, St. George COST No. 1).

R. St. George Basin COST No. 2 Well

The ARCO St. George Basin COST No. 2 well was drilled to a measured depth of 14,626 feet (4,458 meters) at an estimated cost of approximately $31 million. The water depth was 375 feet (114 meters). The well site was approximately 110 miles (177 kilometers) northwest of Cold Bay, Alaska. The well was drilled from the <u>SEDCO 708</u>, a semisubmersible drilling rig. Drilling began on May 19, 1982, and the well was completed on September 2, 1982. There were 19 participants.

Logging runs were made at depths of 4,976 feet (1,517 meters), 10,135 feet (3,089 meters), and 14,622 (4,457 meters). Seventeen conventional cores, 337 sidewall cores, and well cuttings collected at 30-foot intervals from 1,460 to 14,626 feet (445 to 4,458 meters) were analyzed.

Stratigraphic units encountered in the No. 2 well were undifferentiated Plio-Pleistocene to 1,460 feet (445 meters), Pliocene to 4,246 feet (1,294 meters), Miocene to 6,050 feet (1,844 meters), Oligocene to 11,085 feet (3,379 meters), possible Eocene to 12,540 feet (3,822 meters), Lower Cretaceous or Upper Jurassic to 13,370 feet (4,075 meters), and Upper Jurassic to 14,626 feet (4,458 meters) (total depth).

The Cenozoic sedimentary section consists of interbedded sandstone, siltstone, mudstone, diatomaceous mudstone, and conglomerate. These sediments are predominantly from volcanic source terranes. Mineralogically, the sediments are physically and chemically unstable. Porosity and permeability have been reduced by ductile grain deformation, cementation, and authigenesis.

The Mesozoic sedimentary section consists of sandstone, siltstone, shale, conglomerate, and minor amounts of coal. Porosities and permeabilities are low.

Geochemical analyses show a predominantly type III, humic gas-prone kerogen. The section is low in total organic carbon. Siltstones with a very limited potential for generating hydrocarbons are present below 5,100 feet (1,554 meters). Thermal maturation is low. The sedimentary section penetrated appears to be gas prone at best. (Turner et al., 1984, St. George COST No. 2).

S. Navarin Basin COST No. 1 Well

The ARCO Navarin Basin COST No. 1 well was drilled to a measured depth of 16,400 feet (4,998 meters) at an estimated cost of approximately $37.5 million. The water depth was 432 feet (132 meters). The well site is approximately 457 miles (735 kilometers) southwest of Nome, Alaska. Drilling began on May 26, 1983, and was completed on October 22, 1983. There were 19 participants.

Logging runs were made at 5,032 feet (1,534 meters), 11,046 feet (3,367 meters), 12,834 feet (3,912 meters), 15,341 feet (4,676 meters), and 16,385 feet (4,993 meters). Twenty conventional cores, 668 sidewall cores, and well cuttings collected at 30-foot intervals from 1,536 to 16,400 feet (468 to 4,998 meters) were analyzed.

Seafloor instability and gas-charged sediments are major geologic hazards in the Navarin Basin. However, the well was drilled in an area not affected by these potential geohazards. Wireline log and formation test data clearly identify a major zone of abnormal formation pore pressure from 9,430 to 15,300 feet (2,874 to 4,663 meters). Thermally activated stripping of interlayer water from smectitic clays during illitization may be the primary process responsible for the abnormal pressures in this interval.

The well penetrated Pliocene strata from 1,536 to 3,180 feet (468 to 969 meters), Miocene from 3,180 to 5,704 feet (969 to 1,738 meters), Oligocene from 5,704 to 12,280 feet (1,738 to 3,743 meters), Eocene from 12,280 to 12,780 feet (3,743 to 3,895 meters), and Cretaceous from 12,780 to 16,400 feet (3,895 to 4,998 meters). The unsampled interval above 1,536 feet (468 meters) probably contains Plio-Pleistocene and Holocene sediments. With the exception of an Upper Cretaceous coal-bearing section, the fine-grained clastic sediments encountered were all deposited in marine environments. Reservoir characteristics are generally poor, and the best potential reservoirs are located considerably above the oil window. Porosity and permeability have been reduced by compaction, cementation, diagenesis, and authigenesis.

An average geothermal gradient of 1.78°F per 100 feet was calculated from 3,800 to 16,400 feet (1,158 to 4,998 meters). An anomalously higher gradient of 2.5°F per 100 feet above 3,800 feet (1,158 meters) is probably due, at least in part, to the effects of an overpressured zone associated with the complex diagenetic alteration of diatomaceous sediments.

Sufficient thermal maturity for the generation of oil exists below 10,000 feet (3,048 meters). Strata above 15,000 feet (4,572 meters) are thermally immature except where exposed to igneous activity. No significant oil shows were encountered in this stratigraphic test, but relatively greater amounts of methane did occur in sediments down to about 6,000 feet (1,829 meters). This methane is believed to be of biogenic origin. With the possible exception of this light gas, there is no evidence to suggest that any of the hydrocarbons analyzed were not indigenous to the lithologies sampled. Between about 11,700 and 12,780 feet (3,566 to 3,895 meters), the early Oligocene and late Eocene section includes an anoxic marine organic facies. If this lithologic sequence thickens deeper in the basin, significant amounts of oil-prone source rock at a favorable level of thermal maturity could be present. (Turner et al., 1984, Navarin).

Block--A geographical area of approximately 9 square miles (5,760 acres) that is used in official MMS protraction diagrams of leasing maps. See "Tract."

Coastal Zone Consistency Review--Review of Federal licenses or permits and OCS plans pursuant to the Coastal Zone Management (CZM) Act by affected coastal States to determine if the action is consistent with the State-approved CZM program. (This review can take up to 6 months to complete.)

Common Depth Point (CDP)--A common location in the ocean subbottom where sound waves originating from various positions of the seismic (sound) source near the ocean surface are reflected back toward the surface. The traces from different seismic profiles corresponding to the same reflection point are mathematically summed (stacked) for reflection points beneath the survey line.

Continental Offshore Stratigraphic Test Wells (COST)--Deep stratigraphic wells drilled offshore to determine the geological character or stratigraphy of rock strata. These wells, which may be more than 20,000 feet (6,096 meters) deep, provide information that can be used by Government and industry to evaluate tracts to be offered in a lease sale. See "Deep Stratigraphic Test Wells."

Deep Stratigraphic Test Wells--Prelease wells drilled (usually by a consortium of companies) to obtain information on the subsurface geology of an area. Drilling involves penetration into the sea bottom of more than 50 feet (15.2 meters) of consolidated rock or a total of more than 300 feet (91.4 meters) of sediment. Activities involved with these wells are controlled by permits issued by MMS pursuant to 30 CFR 251.

Drillship--A self-propelled, self-contained vessel equipped with a derrick amidships for drilling wells in deep water.

Exploration--The process of searching for minerals preliminary to development. Exploration activities include (1) geophysical surveys, (2) any drilling on or off a geologic structure, and (3) geochemical surveys.

Formation--A bed or deposit sufficiently homogeneous to be distinctive as a unit. Each formation is given a name.

Hydrocarbon--Any of a large class of organic compounds containing primarily carbon and hydrogen. Hydrocarbons include crude oil and natural gas.

Lease--A contract authorizing exploration for and development and production of minerals for a specified period of time over a given area. The meaning of "Lease" depends upon its use in context.

Lease Sale--An MMS proceeding by which leases for certain OCS tracts are offered for sale by competitive sealed bidding and during which bids are received, announced, and recorded.

Limestone--A rock that is formed chiefly through the accumulation of biogenic remains such as shells and corals consisting mainly of calcium carbonate.

Official Protraction Diagram--Leasing maps that designate a planning area by using the Universal Transverse Mercator Grid System and is divided into blocks.

Operator--The individual, partnership, firm, or corporation having control or management of operations on a leased area or under a permit. The operator may be a lessee, permittee, designated agent of the lessee, or holder of rights under an approved operating agreement.

Outer Continental Shelf (OCS)--The part of the continental shelf seaward of the line that marks State ownership; that part of the offshore lands under Federal jurisdiction.

Permeability--The measure of a rock's ability to transmit fluids; a measure of the ease with which fluids can flow through a porous rock.

Permit--The contract or agreement, other than a lease, approved for a specified period of not more than 1 year under which a person acquires the right to conduct (1) geological exploration for mineral resources, (2) geophysical exploration for mineral resources, (3) geological scientific research, or (4) geophysical scientific research.

Porosity--The ratio of the holes, voids, or pores in a rock to its total volume or size. Also, a measure of the capability to contain fluids within void spaces in a rock.

Proprietary Information--Geologic and geophysical data, information, and derivatives thereof that cannot be released to the public for a specified term because of Federal law, regulations, or statutes, or because of contractural requirements.

Reservoir--A subsurface, porous, permeable rock body in which oil or gas or both have accumulated.

Resources--Concentrations of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust. These include both identified and undiscovered resources.

Sandstone--A sedimentary rock made up of sand-size grains that usually consist of quartz more or less firmly united by some cement (as silica, iron oxide, or calcium carbonate).

Seismic--Pertaining to, characteristic of, or produced by earthquakes or Earth vibration; having to do with elastic waves in the Earth.

Seismic Surveys--A method of geophysical prospecting using the generation, reflection, refraction, detection, and analysis of elastic waves in the Earth.

Semisubmersible--A floating offshore drilling structure that has hulls submerged in the water but not resting on the seafloor.

Shale--An indurated rock that is formed by the consolidation of clay or mud.

Shallow Hazards--Potential geological and manmade hazards to exploration on the OCS that are in the shallow portion of the subbottom. Examples include seismicity, active faults, shallow gas deposits, steep slopes, unstable soil conditions, pipelines, anchors, and sunken ships. Shallow hazards may occur in shallow or deep waters.

Source Bed--Rocks containing amounts of organic matter that is transformed into hydrocarbons.

Spud--To begin drilling a well.

Tract--A designation assigned, for administrative and statutory purposes, to a block or combination of blocks that are identified by an official protraction diagram prepared by the MMS. A lease is granted for tract. A tract may not exceed 5,760 acres unless it is determined that a larger area is necessary to comprise a reasonable economic production unit. See "Block."

Trap--A geologic feature that permits the accumulation and prevents the escape of accumulated fluids (hydrocarbons) from the reservoir.

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