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A PRELIMINARY SUMMARY OF PETROLEUM POTENTIAL, ENVIRONMENTAL GEOLOGY, AND THE TECHNOLOGY, TIME FRAME AND INFRASTRUCTURE FOR EXPLORATION AND DEVELOPMENT OF THE WESTERN GULF OF ALASKA

BY

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SUMMARY

This preliminary geology summary of the western Gulf of Alaska has been made to aid the Bureau of Land Management in defining an area for which nominations for oil and gas leasing will be solicited. The suggested area is centered about the Kodiak group of islands and is thought to outline the attractive prospects for oil and gas exploration.

Prospects within the suggested area are three sedimentary basins named Albatross, Tugidak, and Portlock basins. These basins contain an undrilled sequence of sedimentary rocks that have been studied along sparse exposures on the fringes of the Kodiak islands; rocks of equivalent age have been studied just seaward of the continental shelf at sites that were drilled during Leg 18 of the Deep Sea Drilling Project. The sedimentary rocks were found to be analogous to rock sequences in the central Gulf of Alaska and elsewhere. From these studies and a knowledge of the general geologic history of the area, possible reservoir sands are inferred. The thickness of sediments measured in seismic records across the basins are sufficient to assume that hydrocarbon materials have reached maturation.

Albatross basin is the largest of the three, and there are indications that it contains conventional anticlinal structures which could serve as traps for petroleum. The sediments there average about 4 km in thickness along a seismic refraction line on the basin's northeastern flank. A similar apparent thickness of sediments has been measured along the flank of Tugidak basin but because of its smaller areal extent, this basin is considered a somehwat less attractive prospect. Portlock basin appears to be a less attractive prospect because of a probable lesser thickness of sediment.

The undiscovered recoverable resources in the suggested area have been estimated at probability levels of 5 percent and 95 percent to be from 0 to 1.2 billion barrels respectively of oil and from 0 to 3.5 trillion cubic feet respectively of gas. The statistical mean estimates of oil and gas are 0.2 billion barrels and 0.7 trillion cubic feet respectively. It should be remembered that these estimates have been made in advance of any exploratory drilling and are therefore highly speculative.

An analysis of the environmental geology suggests that if pollutant-carrying sediments were being transported across the Continental Shelf, they would probably bypass the fisheries of Albatross Bank. Much of the sea floor is probably covered with glacially derived sediments that may contain large boulders rafted from land by glaciers. Such a sea floor may locally prove difficult for the laying of pipelines, but this inference must be checked by further data. Particular consideration should be given to the potential for large destructive earthquake in this area. Estimates of the frequency of magnitude 7 or greater earthquakes range from 33 years to about 800 years, and a large earthquake during the lifetime of an oil field should be anticipated. Unstable ground and active faults were observed after the great Alaska earthquake of 1964, in particular along a zone south of Montague Island and along Kodiak island. Provisions must be made to accommodate changes in sea floor elevations up to about 10 m in installations on parts of the ocean floor. Plans for coastal activities and installations should include provisions for averting damage from seismic sea waves.

The technology for exploration and development in the Western Gulf of Alaska has been recently demonstrated in comparable North Sea operational conditions. New techniques for measuring and predicting maximum environmental forces are improving the overall capability and reliability of offshore equipment.

Several mobile drilling rigs capable of operations in the Western Gulf of Alaska are presently under construction on the West Coast or Far East; otherwise mobile drilling units must be obtained from the North Sea or other distant parts of the world. The reservoir of skilled manpower in the Alaska area is relatively small due to the low population density and distance from significant industrial centers. Skilled manpower is available in the Pacific Northwest and California.

The time frame for significant development will be relatively long due to high costs and environmental conditions. It is estimated that it will be 2-3 years after a lease sale until substantial exploratory drilling will occur, 7-8 years until initial production, and 10-11 years until maximum production.

Preliminary estimates of peak production and facilities necessary for development are of questionable value in the absence of demonstrated reserves of oil and gas. Owing to the high cost of operations in the Western Gulf of Alaska, economics will restrict development to discoveries that have large recoverable reserves.

INTRODUCTION

This summary of the regional general geology, oil and gas resources, environmental geology, and time frame for exploration of the western Gulf of Alaska Outer Continental Shelf (OCS) area is preliminary to a more complete summary that will be issued about February 1976. The subsequent summary report will be more complete in that it will contain the results of a multichannel seismic-reflection survey conducted during the summer of 1975, that is now being processed, and also data from adjacent areas that are analogous to the western Gulf of Alaska. This preliminary report is meant principally to aid the Bureau of Land Management (BLM) in selecting the area from which to call for nominations.

The report considers a broad region but focuses on an area suitable for initial exploration for frontier oil and gas resouces. The area so defined is between the Gulf of Alaska (proposed sale #30) and Gulf of Alaska-Aleutian Shelf (proposed sale #56) areas and has its northwastern and southwestern boundaries set by them. The seaward boundary and the boundary near Shelikof Strait are set by the 200 m isobath. Northwast of Kodiak Island, the boundary of the area is along State lands as shown in figure 1. The estimates of resource potential and environmental hazards to sea floor installations are considered for the area shown in figure 1. The environmental effects near ports used for staging and fishing are also considered.

The published information on which this report is based is very scanty. Additional unpublished information in the Geological Survey has been used, and the opinions expressed include those of geologists working in this area during the past 10 to 15 years. *See acknowledgements, p. 52. Many of the conclusions, therefore, are qualified by the lack of sufficient data.

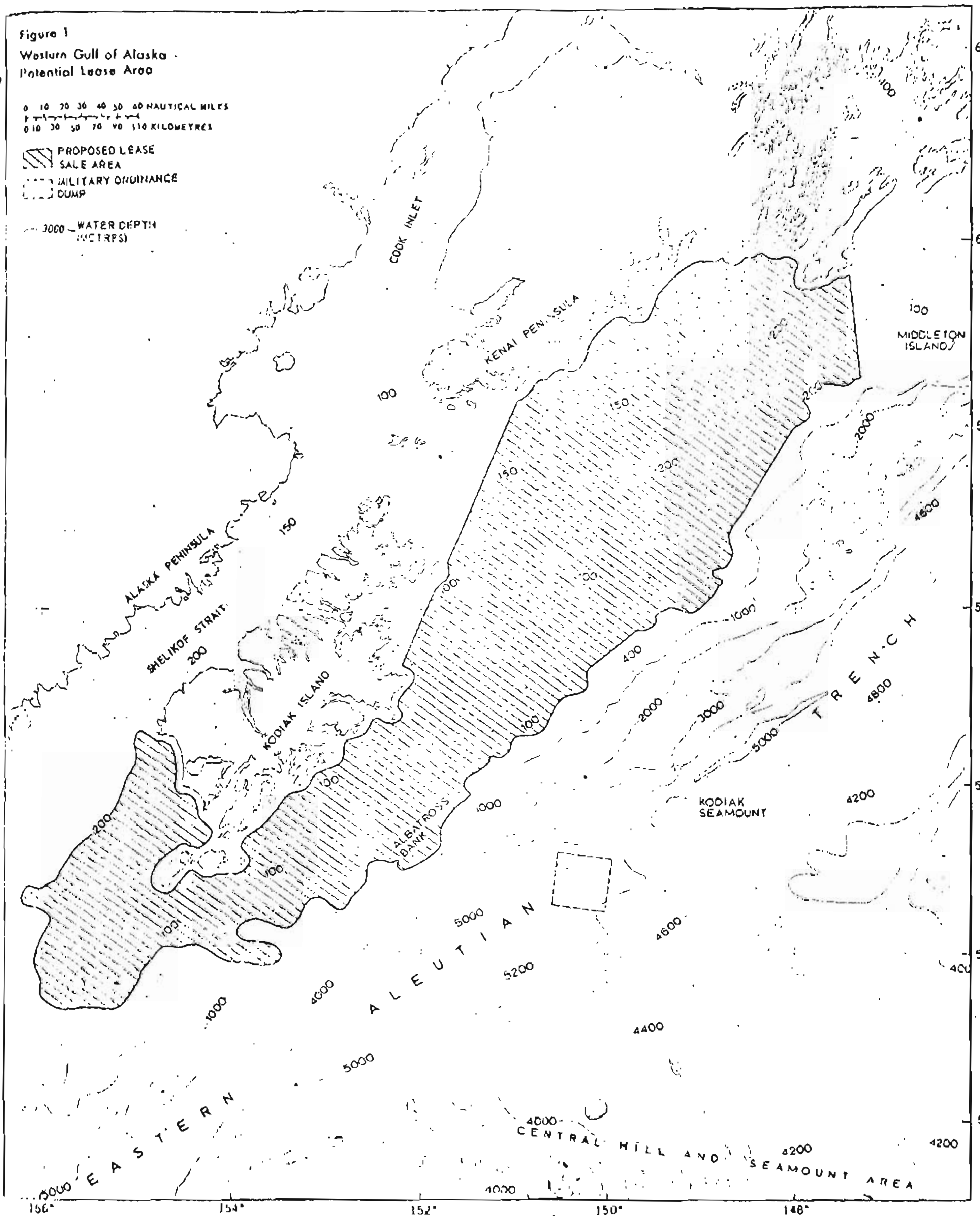


Figure 1
Western Gulf of Alaska -
Potential Lease Area
0 10 20 30 40 50 60 NAUTICAL MILES
KILOMETRES
PROPOSED LEASE
SALE AREA
MILITARY ORDINANCE
DUMP
3000 — WATER DEPTH
(METRES)
COOK INLET
KENAI PENINSULA
ALASKA PENINSULA
SHELIKOF STRAIT
KODIAK ISLAND
ALBATROSS BANK
MIDDLETON ISLAND
KODIAK SEAMOUNT
EASTERN ALEUTIAN TRENCH
CENTRAL HILL AND SEAMOUNT AREA
61°
60°
59°
58°
57°
56°
55°
156°
154°
152°
150°
148°

GEOLOGIC FRAMEWORK

The western Gulf of Alaska continental margin, centered approximately off Kodiak Island, has been named the Kodiak Tertiary Province (von Huene and others, 1971); it is geographically an approximate continuation of the Aleutian Island arc. Two major geologic features also continue, namely, the Aleutian volcanic chain and the Aleutian trench. These major features are associated with a belt of earthquakes accounting for about 7 percent of the annual worldwide release of seismic energy. In the Kodiak Tertiary Province, the major difference from the Aleutian Island arc is the broad Continental Shelf and its insular blocks. Despite this difference, the structural trends of the Kodiak group of islands parallel the Aleutian trend. It has been inferred that these trends represent the remnants of at least two older inactive island arcs and that the present trench formed seaward of them. An idealized geologic cross section through the Alaska Peninsula and Aleutian trench and across Kodiak Island is shown in figure 2.

Lithology

The basement rocks of the western Gulf of Alaska contain what is presumed to be fragments of former oceanic crust (ophiolite) of at least two ages. Oceanic basement rocks of different ages have different overlying metamorphic and nonmetamorphic rock and therefore their potential for petroleum differs also. Except in Shelikof Strait and near the Alaska Peninsula, mildly metamorphosed lower Tertiary rocks constitute a floor to potentially petroliferous rocks in the western Gulf of Alaska.

The Tertiary rocks were deposited on a very thick section of contorted Upper Cretaceous flysch (fig. 2), which has been metamorphosed to slate

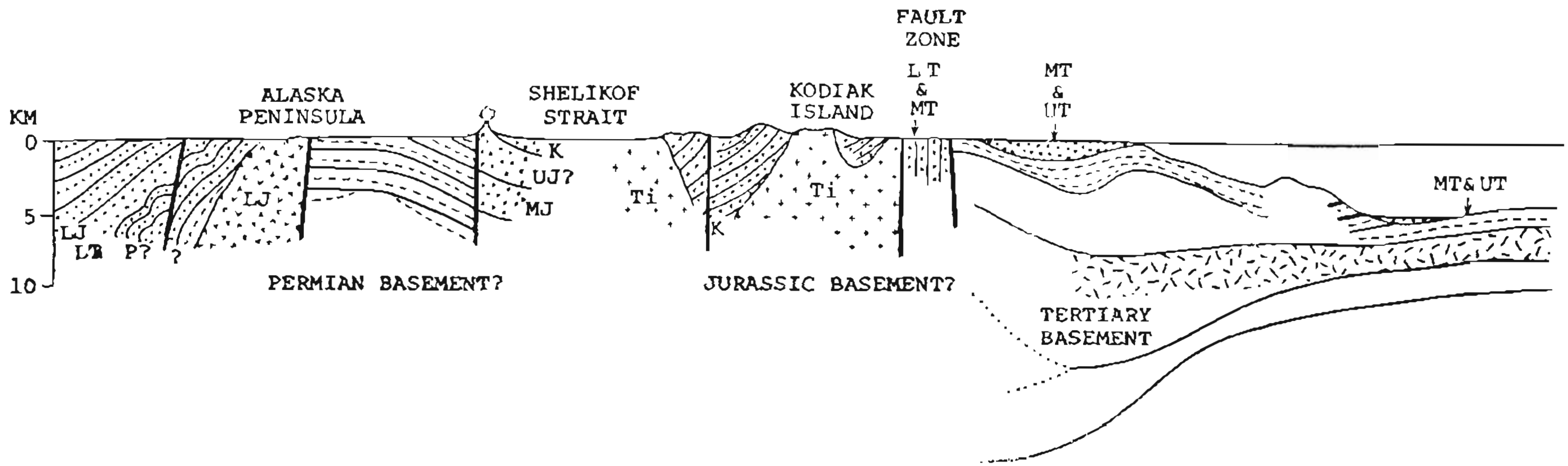


Figure 2

Idealized Geologic Cross Section through Alaska Peninsula, Aleutian Trench, and Kodiak Island grade. It occurs as the Valdez Group on the Kenai Peninsula, the Kodiak Formation on Kodiak Island, and the Shumagin Formation on the Shumagin Islands (Plafker, 1967; Moore, 1969; Burk, 1965). Lowermost Tertiary rocks consist of a sequence of nonfoliated but strongly indurated rocks, chiefly of Paleocene age, that in some places contain pillow flows and volcaniclastic debris. They are generally at the zeolite grade of metamorphism and locally have been intruded by Paleocene plutons. This sequence is called toe Orca Group on the Kenai Peninsula, the Ghost Rocks Formation on Kodiak Island, and the Tolstoi Formation of Burk (1965) along the Alaska Peninsula.

The Ghost Rocks Formation (fig. 4) is overlain by tightly folded Eocene and Oligocene flysch of the Sitkalidak Formation that is estimated to be approximately 3,000 m thick (Moore, 1969). The lower part of the Sitkalidak Formation is nearly as altered and cemented as the underlying Ghost Rocks Formation, but the induration is less near the top, where the formation is conformably overlain by shoreline facies of the Sitkinak Formation. The Sitkinak Formation is of Oligocene age, is about 1,500 m thick, and consists of siltstone, sandstone, and deltaic conglomerate. It contains fossil redwood needles and thin coalbeds. At the type locality on Sitkinak Island, the formation is conformably overlain by mollusk-bearing Miocene siltstone of the Narrow Cape Formation, about 150 m thick. On Chirikof Island, a marine unit 6,000 m thick has been tentatively assigned to the Sitkinak Formation because it contains coal pebbles and thick submarine fanglomerate beds that have clasts similar to those of the deltaic Sitkinak Formation.

On Kodiak Island, the Miocene Narrow Cape Formation is about 700 m thick and unconformably overlies lower Oligocene or Eocene rocks. It consists of fairly well sorted comgolmerate and sandstone, along with siltstone similar to that of the same formation on Sitkinak Island.

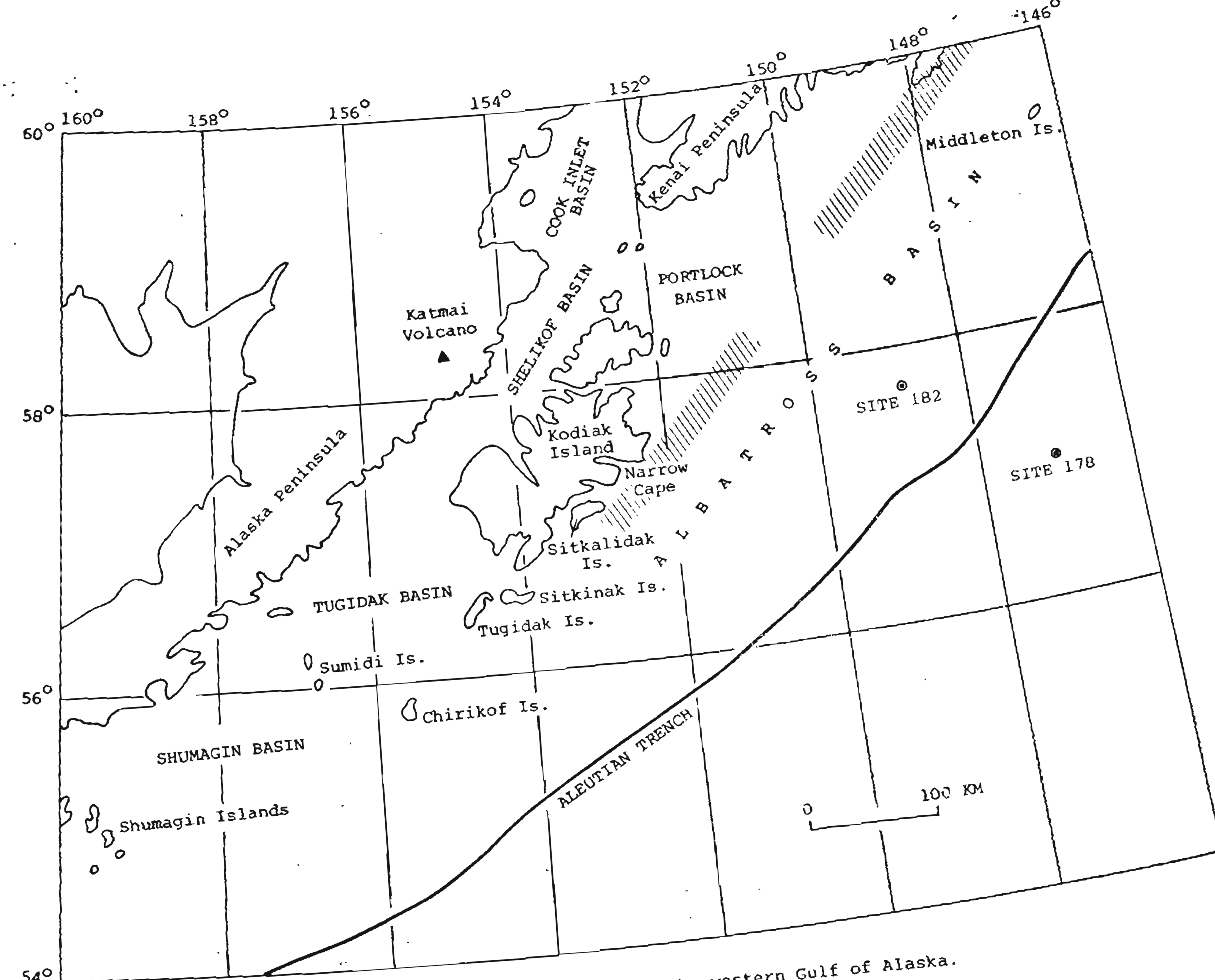


Figure 3. Late Tertiary basins in the western Gulf of Alaska. Hatchured area indicates zone where recent fault scarps have been found.

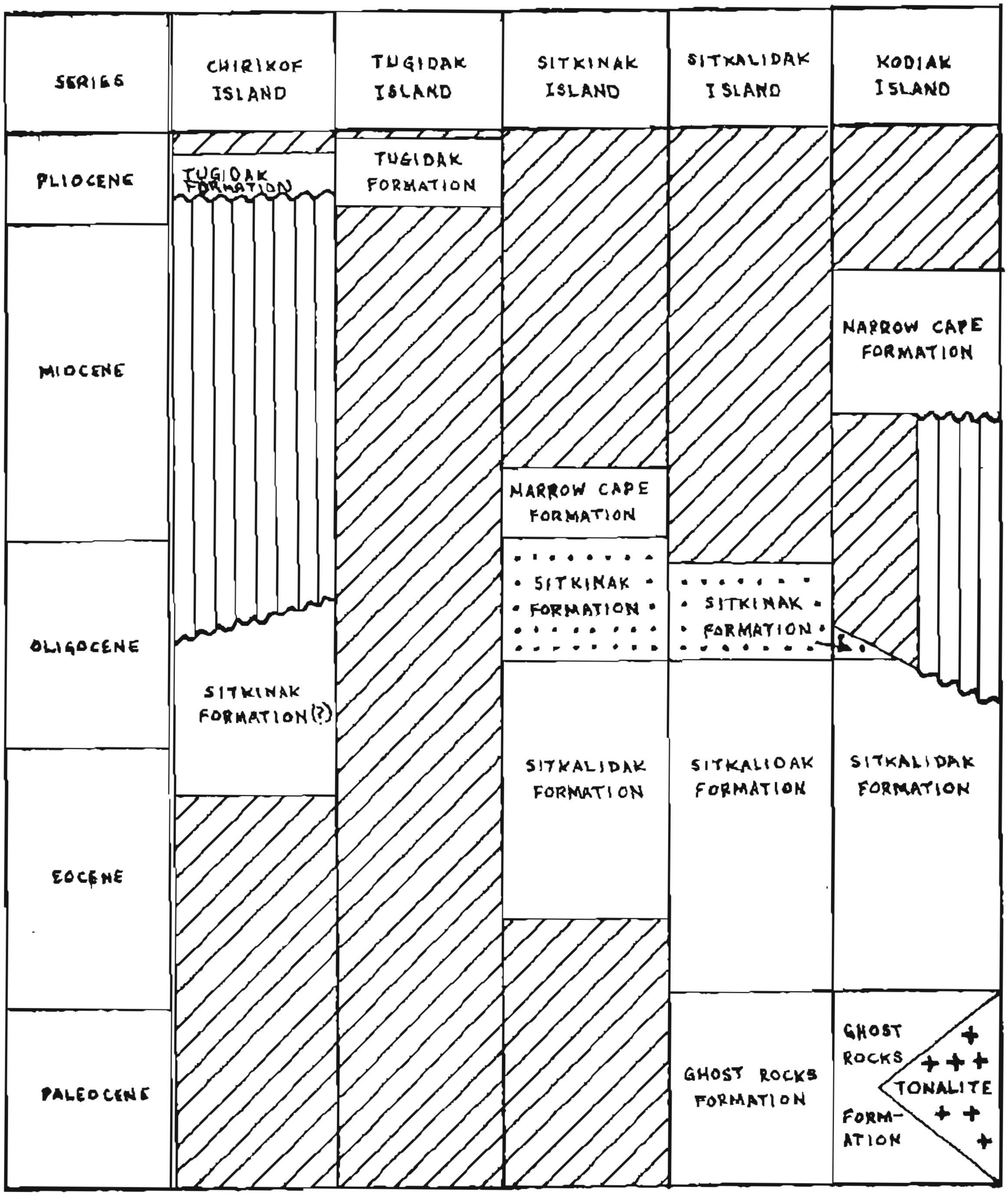


Figure 4. Tertiary rock units on islands in the western Gulf of Alaska. Dot pattern indicates continental rocks; vertical ruling represents missing strata at unconformity; diagonal ruling indicates no data.

The youngest Tertiary formation cropping our on the Kodiak group of islands is the Tugidak Formation of Pliocene age. On Shirikof Island, it is believed to overlie Oligocen rocks unconformably, whereas at the type locality, where the thickness is 1,500 m, the base is not exposed. The Tugidak Formation consists of interbedded sandstone and siltstone containing molluscan fossils. The formation also contains abundant ice-rafted dropstones throughout its thickness.

Seaward of Kodiak Island, a section of probable upper Tertiary sedimentary rocks occurs in basins along the Outer Continental Shelf (von Huene, 1972) (see fig. 3). The rocks in these basins are essentially unsampled; their properties can only be inferred from the small exposures of sedimentary rocks of presumed equivalent age on Kodiak Island, from data from two drill cores in the deep ocean recovered on Leg 18 of the Deep Sea Drilling Project, and from the general geologic history of this region. These rocks appear to be the most promising source of oil and gas because they are generally unmetamorphosed, although older unmetamorphosed rocks of the Orca and Ghost Rocks formations may be discovered by drilling some of the offshore basins. Onshore outcrops are of limited extent, and because of this the Kenai Peninsula and the Kodiak and the Shumagin groups of islands are thought to have been topographic highs that have not served as major depocenters since Oligocene or Miocene time.

Sediments of Miocene through Pleistocene age were recovered at Site 178 of the Deep Sea Drilling Project just seaward of the Aleutian Trench off Kodiak. The Miocene to middle Pliocene section is composed of silt and sand turbidites, including a 70 m section of sand inferred from the seismic records. Above this unit the section is mostly mud and silt and sediments typical of glacial marine environments (Kulm, von Huene, and others, 1973). The source of these sediments was probably from various areas around the Gulf of Alaska but they are thought to be analogous to the types of material in the Kodiak Tertiary Province.

About midway up the Continental Slope at site 182, a 200-m section mainly of Pleistocene age is presumed from drilling characteristics and frequent caving of the hole to be mostly sand, but only small amounts of this sand were recovered. Such large amounts of sand are unusual in a deep-ocean environment.

On Albatross Bank, near the edge of the Continental Shelf off Kodiak, one series of dredge samples has been recovered. The samples are mostly Pliocene siltstone containing an assemblage of Foraminifera indicating deposition in water much deeper than that in which the samples are presently found (von Huene, unpub. data). This suggests that sediments in the core of Albatross Bank may have been deposited in a bathyal environment and may then have been uplifted.

Some inferences based on this sparse information can be made about the Tertiary section under the Continental Shelf near Kodiak. The pre-Oligocene section is generally metamorphosed where exposed and is therefore considered to have a poor potential for petroleum. The post-Oligocene section contains some sand in the shoreward facies as well as at two sites seaward of the Continental Shelf. The presence of sand on the Continental Slope suggests that enough of it was present to bypass the Continental Shelf; therefore sand is likely to occur in the section under the continental shelf.

Structure

The Kodiak Tertiary basin has been divided into three sub-basins, mainly on the basis of gravity anomalies (Barnes, 1967) (fig. 3). Because of the wide spacing of ship's tracks and the generalized response of gravity measurements to structures not associated with large changes in rock density, the boundaries between basins are vague. The diagrammatic geologic section across Albatross basin (fig. 2) is based on geologic and geophysical information. The maximum thickness of the upper sedimentary unit in Albatross basin from seismic-refraction observation is 5 km, and the velocities are those that would be expected from the upper Tertiary rocks exposed on Kodiak Island (von Huene, 1972). The upper unit is slightly thicker than the truncated upper Tertiary sedimentary sequence between Tugidak and Chirikif Islands (von Huene and Shor, 1969 and von Huene, 1972). A seismic-refraction measurement in Portlock basin indicates a thinner unmetamorphosed section. The gravity anomalies over Albatross and Tugidak basins are more negative than that over Portlock basin. Therefore, it may be inferred that Tugidak and Albatross basins have sufficiently thick upper Tertiary sediments of relatively low density to qualify as promising targets for oil and gas exploration. Portlock basin appears to be a target of more questionable potential.

Very little is known about the deeper structures within each of the basins because reflectors from these levels are obscured in single-channel seismic-reflection data. Only structures near the surface or at shallow depth can be seen in this type of information. A large structure corresponding to Albatross Bank appears to consist of a broad discontinuous arch along the edge of the Continental Shelf. The core of the arch has been eroded, exposing upper Miocene and Pliocene strata.

Landward of Albatross Bank are near-surface indications of smaller broad anticlines and synclines. The sparse data only indicate the existence of such structures; data are insufficient to indicate their extent or closure.

A large fault zone near the shore of the Kodiak group of islands is exposed in places on Kodiak Island and may extend northeast of it. The greatest intensity of seismic aftershock activity associated with the great Alaska earthquake of 1964 corresponds to this zone. However, the zone cannot be traced south of the Trinity Islands, and it appears to terminate near the southern end of Kodiak Island.

GEOLOGIC HISTORY

As far as oil and gas prospects are concerned, the most significant period of geologic history in this area was late Tertiary time. Rocks on the islands indicate that the sedimentary environment changed in Oligocene time from deep water to the shallow water environment of the present shelf. Rocks in cores from site 178 indicate that in early Miocene time, rates of deep-ocean sedimentation were slow, and that throughout the Miocene and Pliocene, the terrigenous sedimentation increased progressively. To the north on land, exposed sediments indicate the uplift of the Chugach-St Elias Range and a late Tertiary transition from a warm and temperate low-energy marine environment to a cold temperate higher energy marine environment. Pliocene uplift of the Alaska Range is also indicated. Therefore the data appear to indicate formation of high mountains and mountain valley glaciers along the central part of the Gulf of Alaska in middle or late Miocene time. On the basis of land data, the formation of the present Alaska Peninsula and its volcanic chain took place in early Pliocene time; according to the record of volcanic ash falls in the deep ocean marine sediments, this event occurred at approximately the Miocene-Pliocene boundary.

The following summary of the major events from Miocene time to the present can be inferred from these data. About 20 million years ago, the central Gulf of Alaska was dominated by a deep-ocean pelagic environment which then began to receive increasing amounts of terrigenous debris. Approximately 13 to 14 million years ago, a turbidite environment and large channels existed throughout the gulf. This change in environment was probably contemporaneous with renewed uplift of the mountain ranges around the Gulf of Alaska, possibly in early Miocene time. These mountains were high enough by middle to late Miocene time to serve as sources of large quantities of sediment that flooded the Gulf of Alaska out to its central part. Then early in Pliocene time (about 5 million years ago), volcanic activity marked the development of the present Alaska Peninsula. Glaciation probably began in middle to late Miocene time, and in Pliocene time, sea ice was abundant enough to provide numerous glacial erratics. Both volcanism and ice rafting became especially intense about 1 million years ago.

PETROLEUM GEOLOGY

The petroleum potential of the Kodiak Tertiary province appears to be confined largely to offshore rocks of Miocene age and younger on the basis of exposed rocks although Eocene through Oligocene rocks below the shelf could have potential. Only small exposures of unmetamorphosed Tertiary rocks are found on the islands, and there the pervasive alteration related to Paleocene magmatism is believed to have resulted in the degeneration of any older oil. However, sediments of equivalent age may be less altered offshore nearer the edge of the continental shelf. The petroleum potential of the Kodiak province is inferred partially from the presence of rocks that have characteristics similar to oil-bearing strata elsewhere, especially from known oil and gas accumulations in a similar geologic setting in the onshore portion of the eastern Gulf of Alaska. Inferences about petroleum are also based on the potential existence of reservoir rocks, a sufficient thickness of sedimentary rocks to provide hydrocarbon maturation, and anticlinal structures to serve as traps.

Offshore Tertiary basins are inferred from negative gravity anomalies, from seismic-reflection records, and from outcrops on flanking islands (fig. 3). Local unconformities occur in onshore exposures (fig. 4), and seismic records indicate that the offshore basins also contain unconformities (von Huene and others, 1972). The Tertiary structural and stratigraphic relations of the western Gulf of Alaska closely resemble those of the onshore eastern gulf, where most of the known oil occurs in fractured Oligocene and Miocene rocks (Plafker, 1971). No onshore or offshore traces of oil have been found, although the many young faults might be expected to provide suitable conduits toward the surface for natural seeps; such seeps could be found in the future.

Rocks on the nearshore fringes of the Kodiak Tertiary Province contain sand suitable for petroleum reservoirs. Samples from the deep ocean indicate that enough sand was available to go beyond the Continental Shelf. Therefore sand may have been deposited in large enough quantities to form reservoirs under the Continental Shelf; at present, this supposition is highly conjectural.

Available data show a sufficiently thick section of upper Tertiary rocks to provide an environment for probable maturation of hydrocarbons. Another possible source rock may be the underthrust or subducted oceanic and trench sediment that is presumed to underly Albatross Basin. Maturation of hydrocarbons in these sediments is reported in a Pliocene-Pleistocene sample from the landward wall of the Aleutian trench as well as abundant organic material in sediments just seaward of the subduction zone that are probably similar to the subducted sediments (von Huene and Kulm, 1973). Closer to Kodiak Island the latent heat from mid-Tertiary intrusion may provide higher than normal temperature gradients.

One large structure that might be a trap for oil is the arch at the edge of the continental margin, but it is deeply breached, and it may therefore have a diminished potential for petroleum. Broad anticlinal structures crossed by single seismic-reflection transects might have closure, but public data are insufficient to confirm this possibility. Present data would favor Albatross basin as the most attractive for conventional targets, followed by Tugidak basin and, lastly, Portlock.

Appraisal Procedures

Estimates of undiscovered recoverable oil and gas resources of the Kodiak Tertiary Province have been prepared as follows: 1) by reviewing the available geological and geophysical data, 2) by applying a vareity of resource-appraisal techniques to these data, and 3) through individual and group appraisals involving subjective probabilities and the application of appropriate statistical procedures (Raiffa, 1968).

Geologic data from the Kodiak Tertiary Province were summarized on data formats that contain an inventory of the information base and a quantification of the summarized information needed to characterize the basic geology. Emphasis was placed upon accuracy of areal determinations of thicknesses and volumes of geologic units and upon selection of an analogous developed area.

A series of geologic and volumetric-yield analog procedures was applied to the Kodiak Tertiary Province to determine a range of hydrocarbon yield values. Analogs for which volumetric yield data were available were limited to the United States and Canada. The most nearly analogous known basins are the adjoining Eastern Gulf of Alaska Tertiary Province and westernmost Oregon-Washington, including offshore. Neither area now has established commercial production, although each is at an early stage of exploration. Each has recorded subeconomic production; such as that at the Katalla field, a small abandoned deposit that produced onshore at the margin of the Gulf of Alaska. Inasmuch as no totally satisfactory productive analogs are available, our analog calculations are considered particularly uncertain.

As a consequence, emphasis is placed on a suite of Hendricks' yield categories which have been calculated.

The Resource Appraisal Group, after review of the geologic and appraisal data at hand, made estimates of undiscovered recoverable resources. These estimates were made both individually in group session; after review, these estimates led to a final-consensus "raw" estimate of undiscovered recoverable oil and gas. The appraisal was made by a subjective probability technique that involved an initial series of estimates conditioned upon the existence of recoverable oil and gas in the province:

1. A low resource estimate corresponding to a 95 percent probability (19 in 20 chances) that there is <u>at least</u> that amount present.

2. A high resource estimate with a 5 percent probability (1 in 20 chances) that there is at least that amount present.

3. A modal estimate of the resource that the estimator associates with the highest probability of occurrence that there will be that amount.

4. A statistical mean that is calculated by adding the low value, the high value, and the modal value and dividing the sum by 3.

A corollary probability assessment also was made regarding the assumption or condition that commercial oil and (or) gas exists. In the initial resource appraisal for the province, the assumption was made that oil and gas does exist in commercial quantities. This assumption cannot be made with certainty in frontier OCS areas in which no petroleum has been discovered to date, as in the Kodiak Tertiary Province. It was therefore necessary to assign a marginal probability to the event "commercial oil found" and to the event "commercial gas found." The probability of finding no oil and gas was estimated as 40 percent (corresponding to a 60 percent probability of finding oil or gas in commercial quantities).

Judgements expressed by the Resource Appraisal Group for the Kodiak Tertiary Province were limited to the conditioned judgement of quantities associated with the 5 percent and 95 percent range and modal estimate and were selected to account for at least 90 percent of the range of undiscovered oil and gas resources. These values of low (95 percent), high (5 percent), modal estimate, calculated mean, and marginal probability are the raw data that were statistically analyzed. A lognormal distribution was fitted by computer program to the high, low, and modal value of the raw estimates to computer the probability distribution (Kaufman, 1962).

For the Kodiak Tertiary Province, curves were thus computed incorporating the associated marginal probability. These curves for oil and gas are shown in figures 5 and 6 and can be used to provide estimates of undiscovered recoverable resources at any chosen probability. For example, the estimated undiscovered recoverable oil at a 1 percent probability (1 in 100 chances) is <u>at least</u> 3.6 billion barrels.

Appraisal of the Proposed Area

This assessment provides the following estimate of <u>at least</u> these amounts at the indicated probabilities:

Undiscovered recoverable resources

	95 percent probability	5 percent probability	Statistical mean
OIL (billions of barrels)	0	1.2	0.2
GAS (trillions of cubic feet)	0	3.5	0.7

Kodiak Tertiary Province
(0-200 m.)

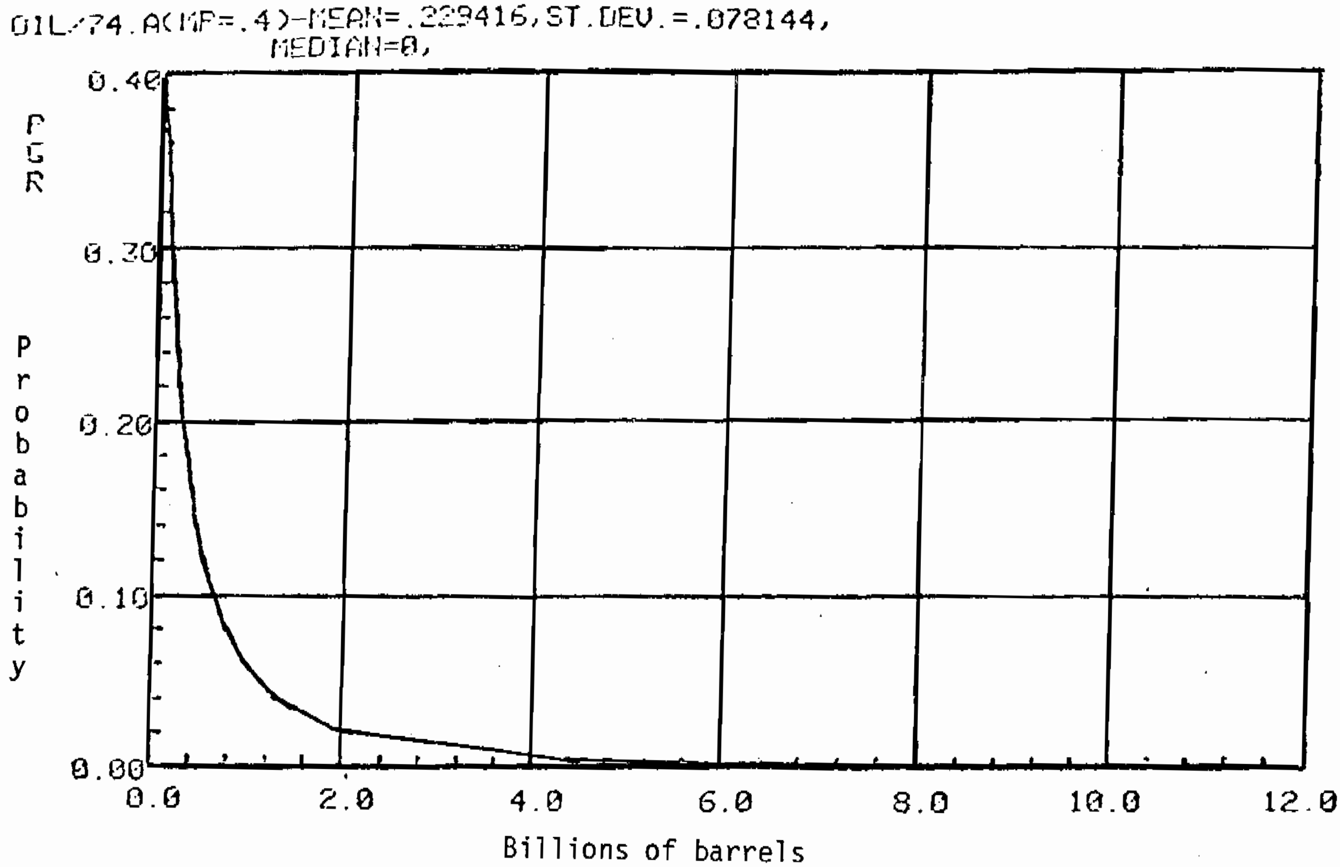


Figure 5.--Undiscovered Recoverable Oil

Kodiak Tertiary Province
(0-200 m.)

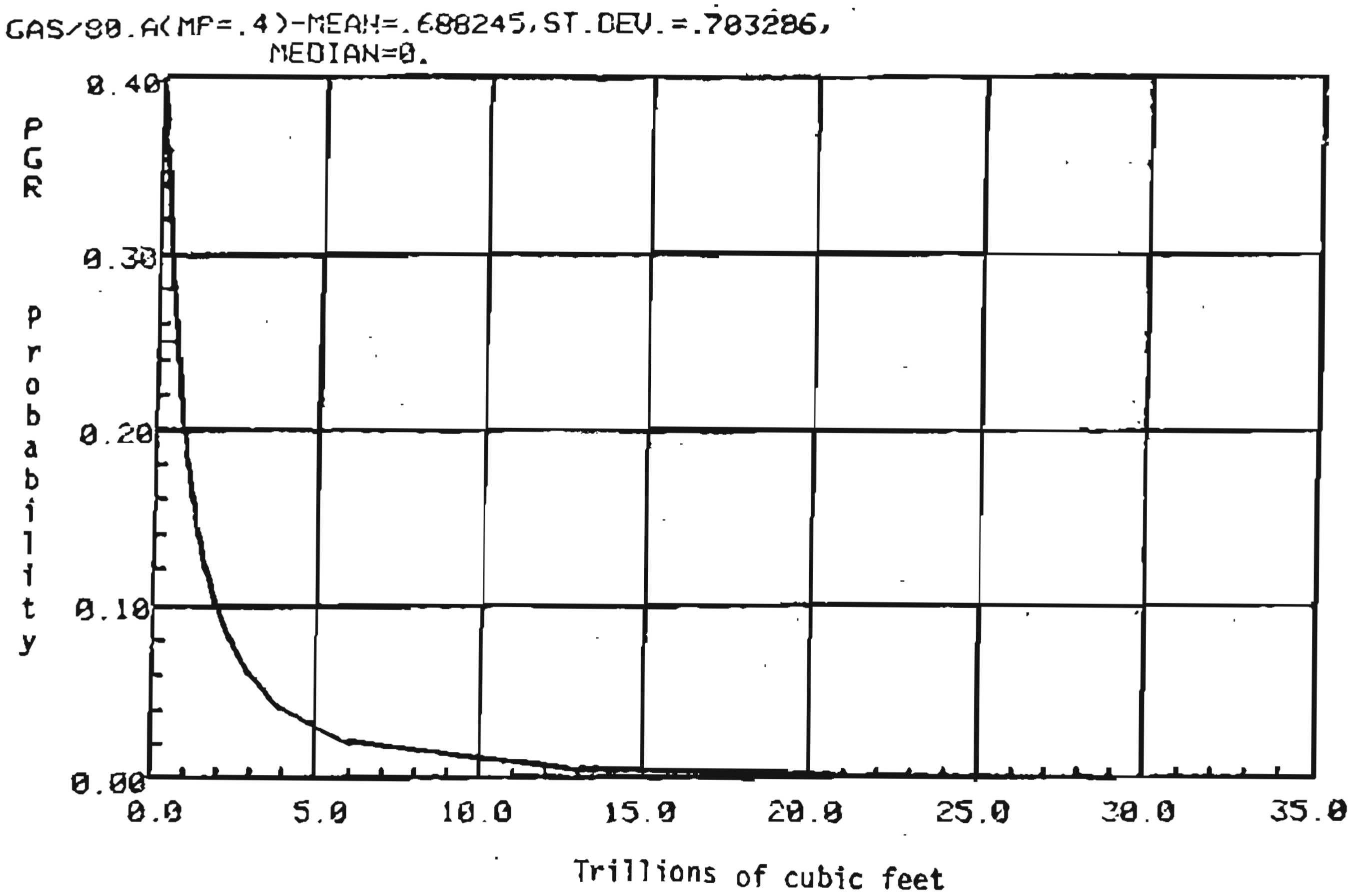


Figure 6 .--Undiscovered Recoverable Gas

Additional hydrocarbons, occurring as natural gas liquids, might be anticipated if quantities of natural gas were to be discovered. Data do not permit direct estimation of these liquids here. However, on a national basis, the NGL/gas production ratio is approximately 33 barrels of NGL for each million cubic feet of gas produced.

ENVIRONMENTAL GEOLOGY

Introduction

Considered under environmental geology in an early stage of the development of knowledge are, 1) possible geologic hazards to seafloor installations and onshore support facilities, 2) geologic characteristics of the ocean floor which might affect the habitat of benthic communities, and 3) possible pathways of pollutants in sediments. This discussion includes both the offshore and the adjacent coastal areas where significant petroleum related activity is likely.

Seismicity

Seismic history

The Gulf of Alaska - Aleutian area is one of the most seismically active in the world, accounting for about 7% of the world-wide release of seismic energy annually. Most of this energy release is associated with large earthquakes (greater than magnitude 7).

The western Gulf of Alaska, between longitude 150°W and 165°W, has experienced about 62 potentially destructive earthquakes ($M > 6$) since 1902, and substantial evidence suggests the likelihood of a major earthquake in the western gulf. Earthquake reoccurrence intervals within a given area along the Gulf of Alaska-Aleutian system have been estimated by various geoscientists. A maximum average reoccurrence interval of about 800 years has been estimated from geologic evidence and the uplift sequence of Middleton Island (Plafker, 1971). On the basis of historic seismic patterns recorded over the past 75 years, Sykes (1971) estimated a minimum interval of 33 years. The occurrence of a major earthquake within the lifetime of a major oil-producing province in this area is reasonable to expect.

Possible Earthquake Effects

The direct effects of the 1964 Alaska earthquake, including ground rupture along faults, surface deformation, and ground shaking, produced less loss of time and property damage than the indirect effects of the seismic sea wave (tsunami), landslides, slumps, and consolidation of sediment. All these processes, therefore, must be considered in evaluating the potential earthquake hazards of this area.

Surface rupturing associated with fault movement in the western gulf has been concentrated offshore; a fault zone in which some faults have been recently active has been identified along a zone that extends from Montague Island to the Kodiak island group (fig. 3) (von Huene and others, 1972). Detailed seismic-survey data are needed to define specific faults that could have surface displacements.

Surface deformation accompanying the 1964 earthquake caused a landward tilting of the continental margin, involving an offshore zone of uplift extending at least to the outer edge of the Continental Shelf and a shoreward zone of subsidence extending onto the mainland. Future major earthquakes in the general area of proposed leasing could produce similar deformation. Maximum uplift in the 1964 event was about 15 m (Malloy and Merrill, 1972), and maximum subsidence was about 2.5 m (Plafker, 1969), indicating the probable magnitude of vertical displacement that could accompany a major earthquake.

Tectonic deformation can produce problems both for shipping and for grounded installations. Along the coastline, tectonic uplift can elevate docks and facilities out of reach of water, as occurred at Cordova where the 1964 earthquake resulted in 3 m of uplift (Eckel, 1969). Tectonic subsidence of coastlines, on the other hand, can lower facilities, thus flooding them or making them more susceptible to destruction by seismic sea waves. Similarly, offshore installations might be raised or lowered to undesirable or nonworkable positions.

Vertical tectonic displacements associated with the 1964 earthquake were largely submarine, a condition that produced a major tsunami. A Tsunami occurs as a train of long-period waves that radiates energy outward from its source in a pattern controlled by the geometry of sea floor and coastline. A tsunami seldom causes damage in the open ocean; its potential destructive force is at a maximum at the coastline. Runup of a tsunami is greatest if the waves reach the shoreline at or near the time of high tide.

Tsunamis do not occur with every submarine earthquake. However, if one should be generated along the western Gulf of Alaska shelf, maximum radiation of energy expectably would be directed toward the southern coasts of the Alaska Peninsula, the Kodiak islands, or the Kenai Peninsula, and severe damage could be expected at one or more of these places.

Destructive waves other than regional tsunamis accompanied the 1964 earthquake. Local tsunamis are produced when water masses are displaced by large rockfalls or submarine landslides; they occurred within the steep-walled fiords in which Seward and Valdez are situated. Deltas constructed of rapidly deposited sediment exist in the heads of many fiords; these sediments are especially susceptible to earthquake-induced sliding and may produce destructive local waves. Damage caused by locally generated waves usually is confined to the embayments within which they originate. However, they must be regarded as particularly dangerous because they strike without warning, during or shortly after the earthquake. Local tsunamis caused more loss of life than any other single cause associated with the 1964 Alaska earthquake.

Waves produced by submarine landsliding are an indirect hazard associated with slides, but slides are a direct hazard themselves if manmade structures are located on the affected material. The alluvial deltas at the heads of many of Alaska's fiords are appealing sites for construction because they commonly are the only extensive flat ground along the coast, but many of these deltas are especially prone to earthquake-induced liquefaction and sliding because of their loose water-saturated sandy nature. Underwater dispersal of slide sediment also poses a problem. The sediment can travel a few miles from the origin of the slide, perhaps as a turbidity current, and cause burial or physical damage to installations on the sea floor.

The offshore shelf sediment in the gulf, away from deltas, is not likely to liquefy during earthquakes because it probably is normally consolidated as a result of slow deposition and reworking by currents. However, large-scale block slumping can occur on submarine slopes and has been identified in the nearby eastern Gulf of Alaska in U.S. Geological Survey high-resolution seismic profiles (P. R. Carlson, oral commun., 1975). These slumps probably are earthquake induced. Much more study is needed to determine the seismic stability of offshore shelf sediments of the western gulf.

Consolidation of sediment and the resulting ground subsidence, without horizontal sliding, is another expectable earthquake hazard in coastal areas. For example, consolidation of sediment on Homer Spit contributed to the closing of port facilities there after the 1964 earthquake (Waller, 1964), as also was a cannery site at Shearwater, Kodiak Island. Consolidation subsidence occurs in areas underlain by loosely packed sediment whose structure collapses during an earthquake and expels intergranular pore fluids. The probability and extent of consolidation subsidence in offshore areas is unknown at this time.

Volcano Hazards

The western Gulf of Alaska region contains 17 volcanoes that have been active within the past 10,000 years or so; eight of these have been active since 1700 A.D. The volcanoes occur along the entire Alaska Peninsula and continue up to the northwest side of Cook Inlet (fig. 7). The risk of damage from volcanic activity in the western gulf, away from the immediate vicinity of the volcanoes, would be principally from ash falls. Any of the 17 volcanoes can be suspected of future activity. They characteristically eject pyroclastic material ranging in size from dust to a few metres in diameter, sometimes depositing significant thicknesses of ash more than 150 km away from the volcano.

Sedimentation

The unconsolidated sediments of the western Gulf of Alaska Continental Shelf form a thin veneer generally less than a few tens of metres thick over bedrock. Bedrock is exposed locally at the surface, in particular, along some of the eroded or faulted parts of the tectonically uplifted outer shelf. The sediments of the western gulf area have received little study, most of our present knowledge being from widely spaced core samples taken by Russian scientists.

Compositionally, the sediments are mostly terrigenous material of glacial derivation, transported to the shelf during Pleistocene low stands of sea level (fig. 8). Volcanic debris is a significant component of the sediment adjacent to the eruptive centers of the Alaska Peninsula and near the Kodiak Islands. Localized deposits of shell material exist, especially along shelf-edge banks.

Mean grain sizes of sediments are distributed in a depth-graded pattern, the coarsest material (pebbles to sand) covering the relatively shallow plateaus, banks, and shoals to a water depth of about 80 metres (fig. 9). Finer grained sands, silts, and muds occupy the deeper areas of the shelf,

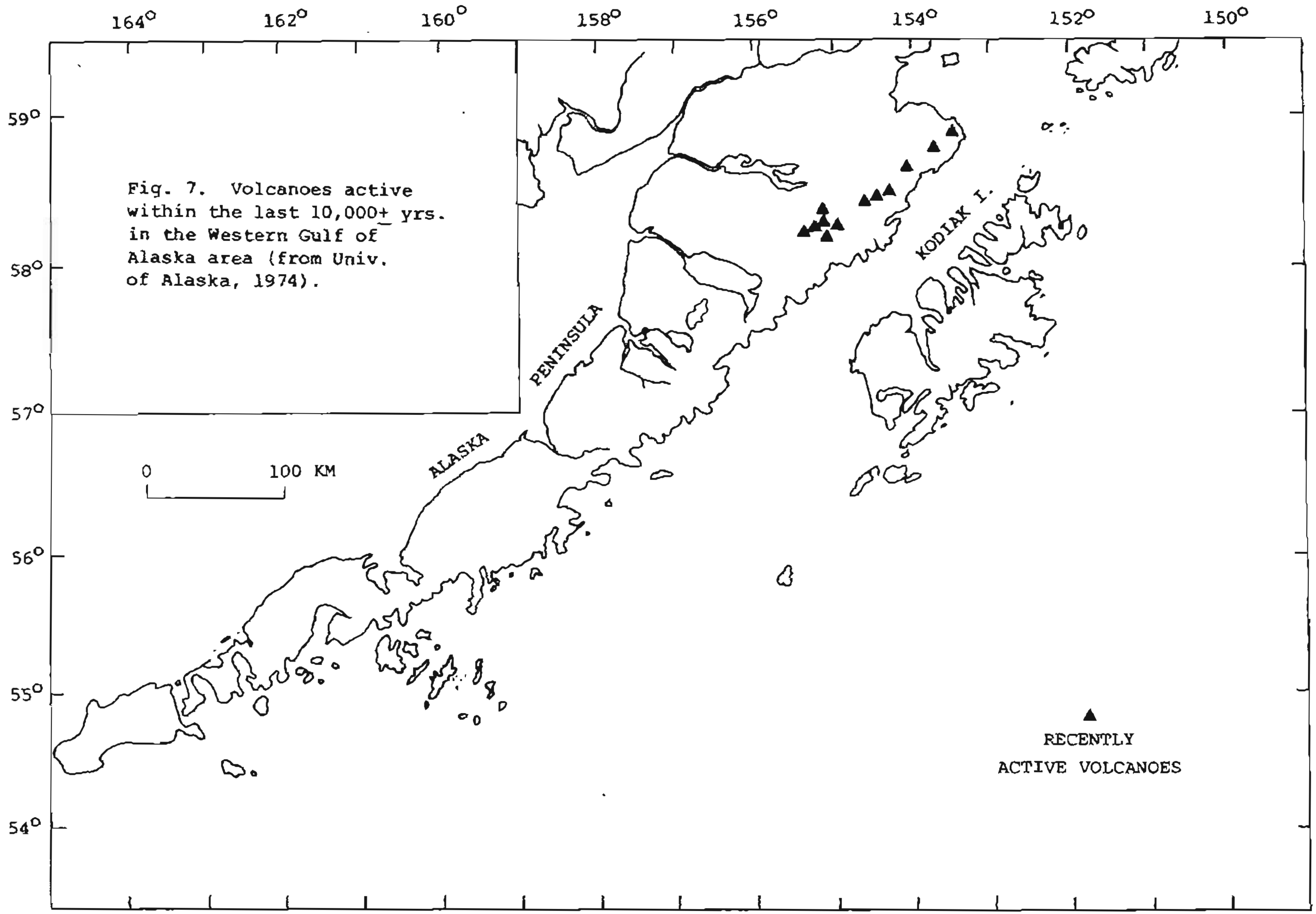


Fig. 7. Volcanoes active within the last 10,000$\pm$ yrs. in the Western Gulf of Alaska area (from Univ. of Alaska, 1974).

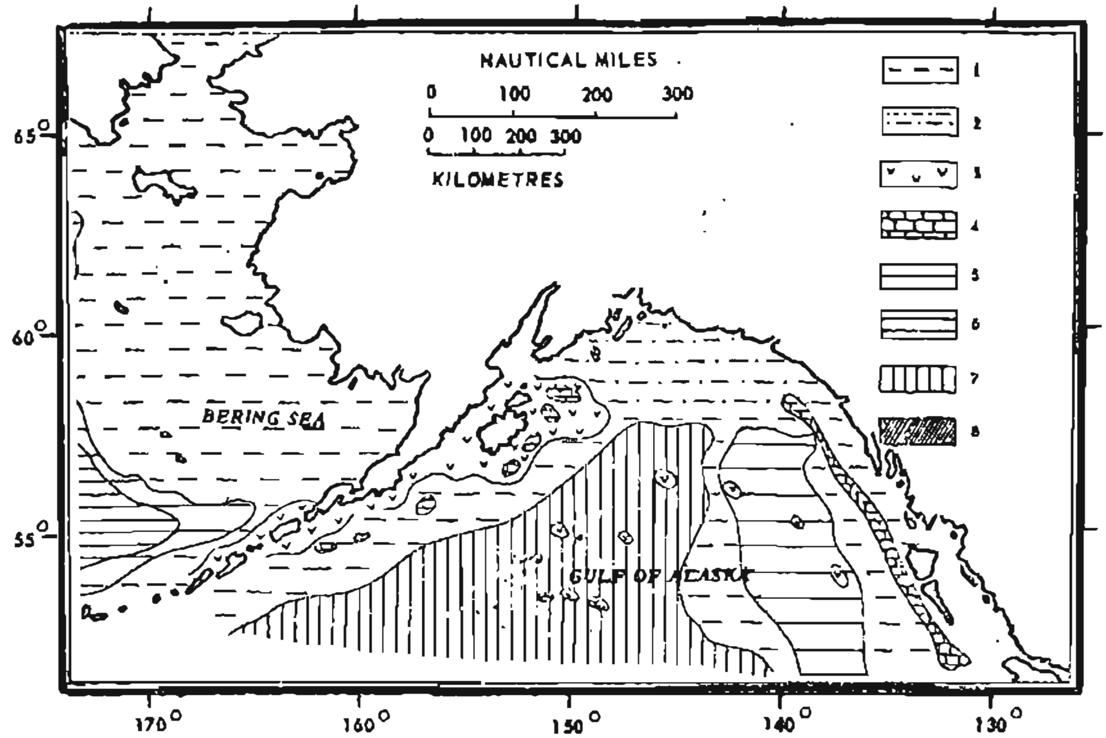
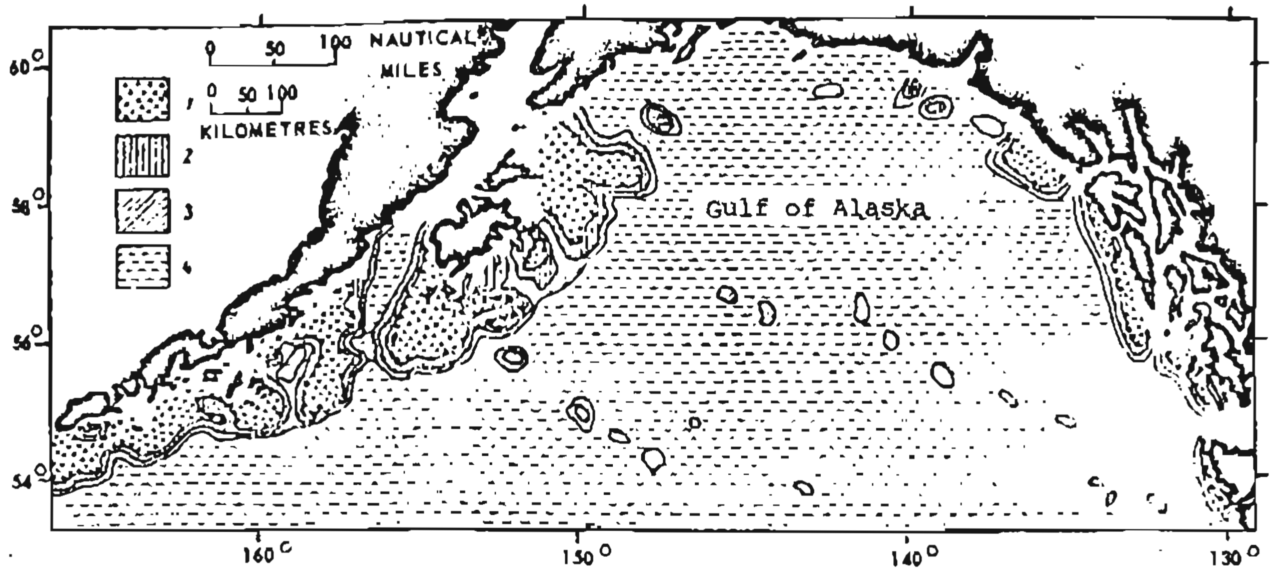
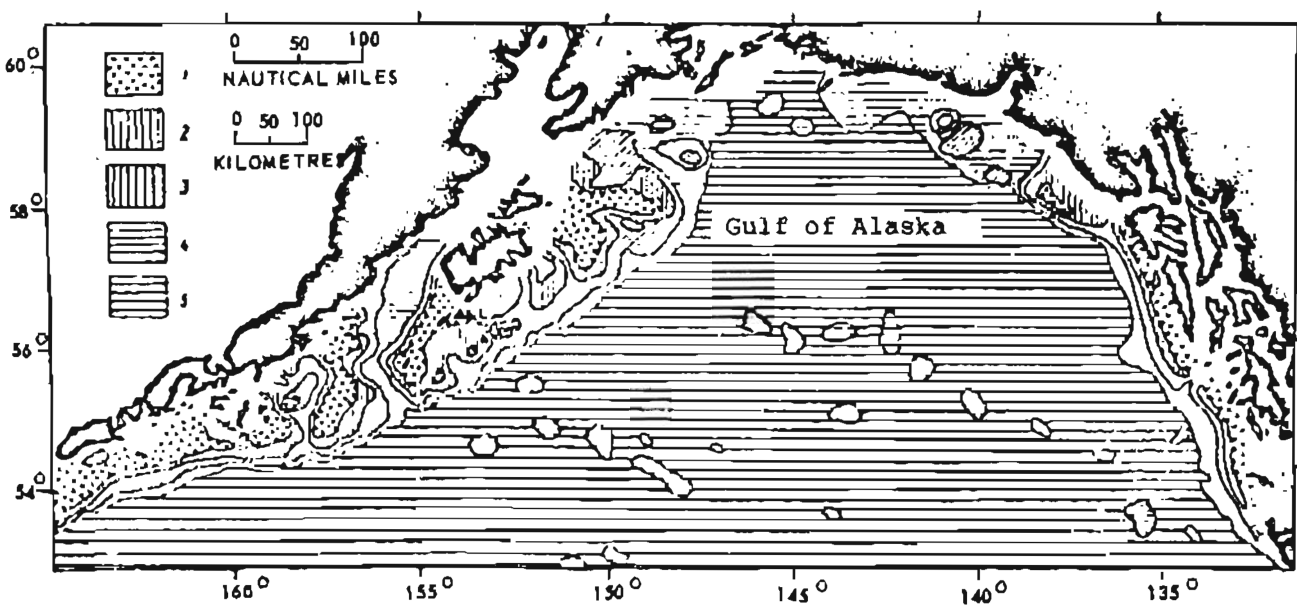


Figure 8 - Composition of sea-floor sediments in the Gulf of Alaska and the Bering Sea. 1 - terrigenous; 2 - glacial marine; 3 - volcanogenic; 4 - shell debris; 5 - slightly siliceous; 6 - siliceous; 7 - deep-sea brown; 8 - mixed. (from Gershanovich, 1968).



A. Sketch map of the distribution of dominant fraction in recent sediments in the Gulf of Alaska. 1) sand and coarse sand; 2) coarse silt; 3) fine silt; 4) pelite.



B. Sketch map of the distribution of particles smaller than 0.01 mm (pelite) in recent sediments in the Gulf of Alaska, %, 1) <5; 2) 5-15; 3) 15-40; 4) 40-70; 5) 70.

Fig. 9. Size distributions of sea-floor sediments in the Gulf of Alaska (from Gershanovich, 1968).

such as the sea valleys. The distribution of grain sizes probably reflects glacial processes during Pleistocene low stands of sea level, modified by modern processes of sediment dispersal. The coarse sediment of the shallow areas appears to be glacial, glaciofluvial, and volcanic debris that has been winnowed and shifted by waves, ocean currents- and perhaps tsunamis. Some of the glacial material might contain abundant boulders, posing a problem to excavation of the sea floor, as might be done to bury pipelines. The deeper areas of the shelf, below the effects of normal waves and currents, probably serve as repositories for the fine-grained material winnowed from the adjacent shallow-water sediments. Tidal currents from Cook Inlet are thought to transport and deposit much land-derived fine sediment on the floor of Shelikof Strait (Univ. Alaska, 1974). The other deep areas of the shelf, especially the continuous sea valleys (fig. 1), might also receive a significant amount of their fine-grained sediment from sources on land, if sediment bypassed through fiords and bays is directed to these deep areas by bathymetrically controlled ocean currents. Insufficient data exist to confirm this idea, however.

Although the details of the circulation of shelf waters are poorly known, the prevailing geostrophic and wind-driven currents probably flow from east to west, and regional sediment drift within the water column and on the sea floor expectably is also in this direction. Current directions and sediment drift in some nearshore shallow and constricted areas might differ from this, however, because of bathymetric deflection and (or) dominance of tidal currents. A much better picture of the paths of ocean currents and sediment transport over the western gulf shelf should be obtained, because pollutants introduced into the shelf environment will be dispersed in a pattern that follows the currents. Moreover, pollutants are transported as adsorbed coatings on individual sediment grains and reside for long periods of time in sediment upon which bottom-living organisms feed.

Because of lack of data, the hazards associated with the stability of shelf sediment on the western gulf Continental Shelf are uncertain at present. The thin deposits of coarse material in the shallow flat areas probably are relatively stable, although periodic net transport might occur during storm-wave conditions. Slumping is a definite possibility along the sloping margins of sea valleys, especially if unusual thicknesses of fine-grained sediment have accumulated. These areas would be especially unstable during earthquakes.

In some coastal areas, tsunamis and seiches could be expected to redistribute significant amounts of sediment. Reimnitz and Marshall (1965) reported temporary shoaling of 30 feet in some channels in Orca Inlet, Prince William Sound, after the 1964 earthquake. The channel fill evidently was eroded from nearby tidal flats by seiche surges. Tidal currents were later able to redeepen the channels.

TECHNOLOGY, TIME FRAME, AND INFRASTRUCTURE NEEDED FOR EXPLORATION AND DEVELOPMENT

Operations in the Western Gulf of Alaska will be influenced to a great degree by environmental conditions in the form of relatively harsh climate, weather and sea conditions and possible seismic disturbances. In addition, a shortage of exploration drilling units and skilled manpower and the remoteness from industrial areas and supply centers could contribute to delays in the time frame for development and to increasing capital layout.

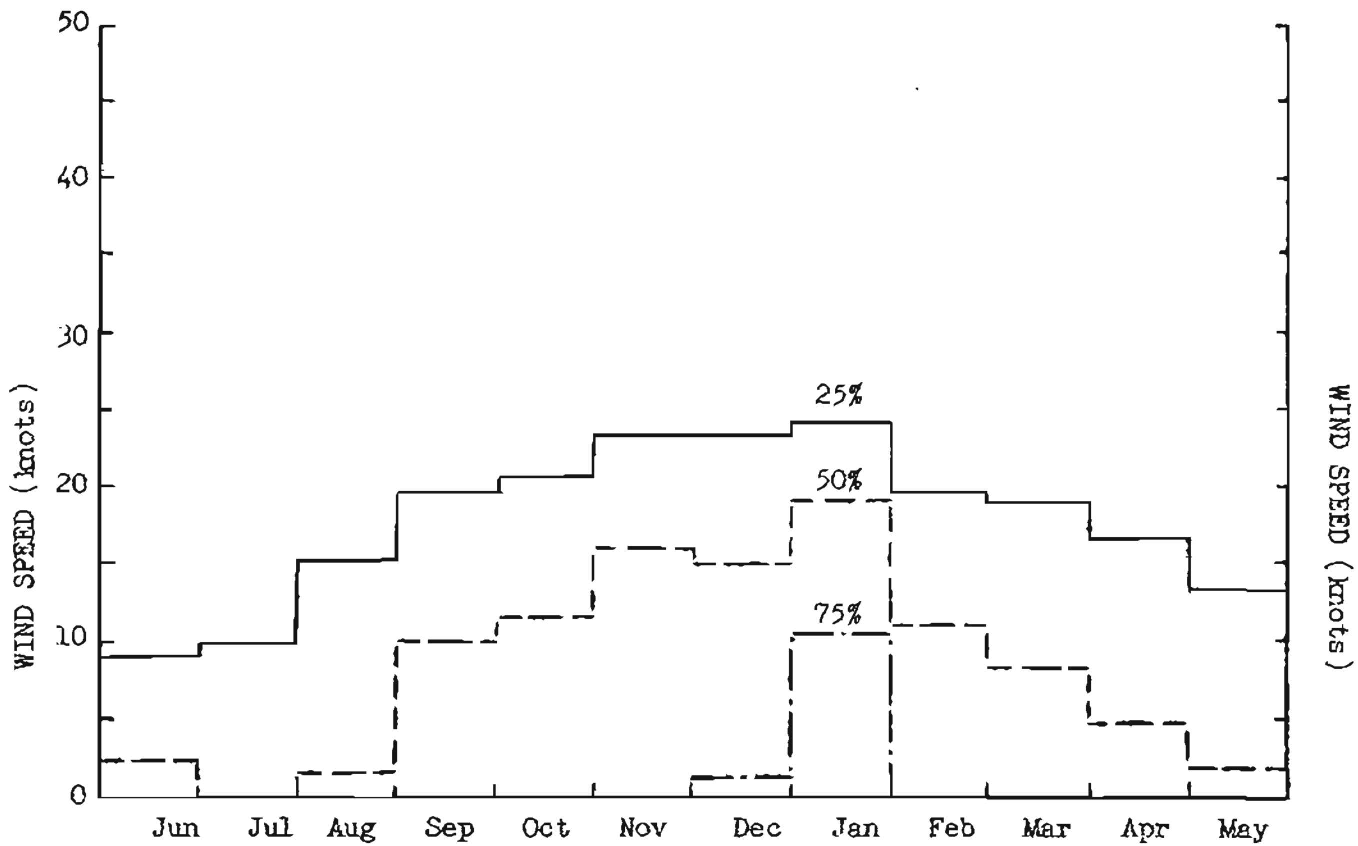
Technology

The following are some of the more important requirements which will influence technology and operational activities in oil and gas development.

1. Climate, weather, and sea conditions will be a major consideration in the design and emplacement of offshore exploration, production, and transportation equipment and facilities. Severe fall and winter weather and storms with extreme winds of 120 mph (193 kmph) and waves of 60 feet (18 m) will affect design criteria and will hamper operational activities during that period (Searby, 1969). The monthly variation of wind speeds in the Gulf of Alaska is indicated in figure 10. The recurrence interval of wind speeds is given in figure 11. The seasonal variation of wave heights in the Gulf of Alaska is indicated in figure 12. The recurrence interval of wave heights is given in figure 13.

2. Potential seismic loading and earthquake effects must be considered in combination with other design criteria for all offshore and onshore structures and facilities.

MONTHLY VARIATION OF WIND SPEEDS

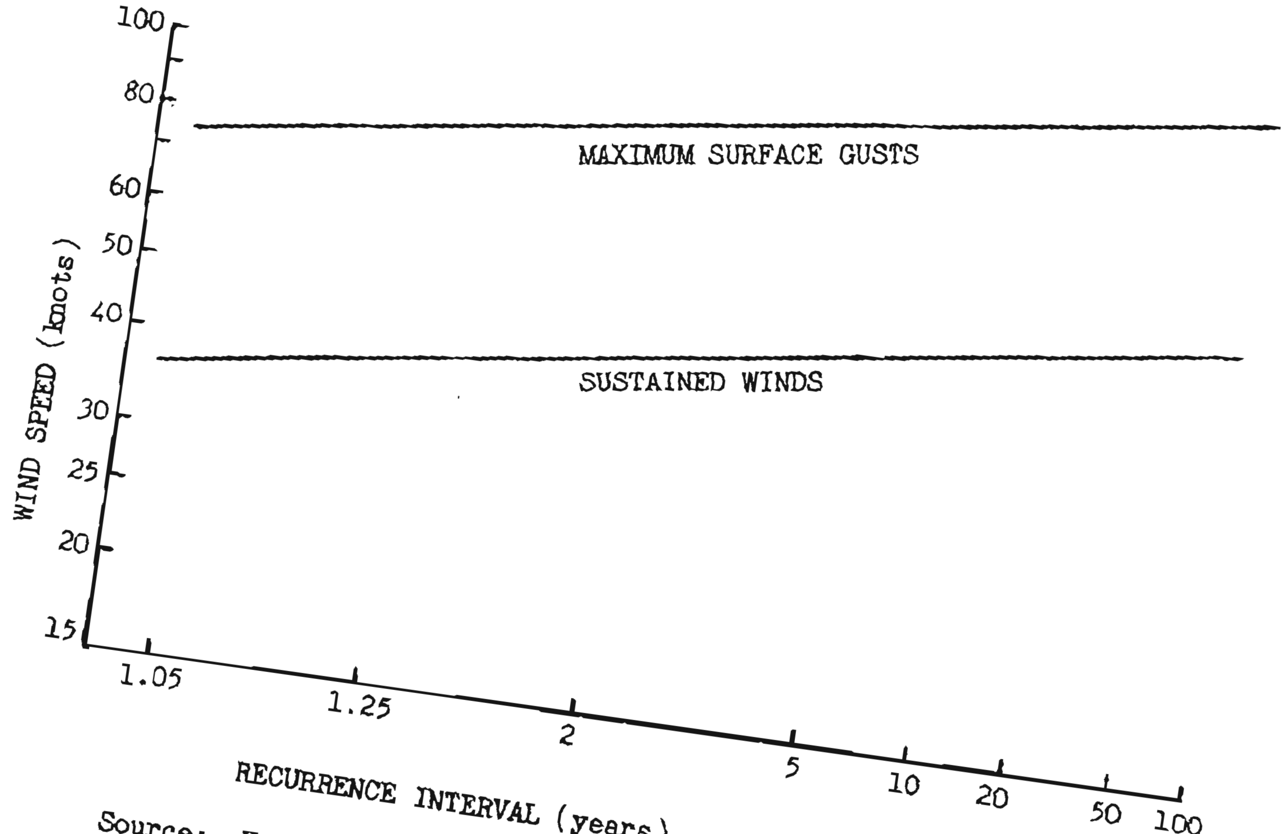


Probability of Wind Speeds ≥ Indicated Value

Source: Horrer, P.L., 1975, Statement before the U.S. Department of Interior, Bureau of Land Management Hearing on Proposed Oil and Gas Leasing on the Outer Continental Shelf, Northern Gulf of Alaska, Aug. 12-13, 1975, Anchorage, Alaska.

Figure 10

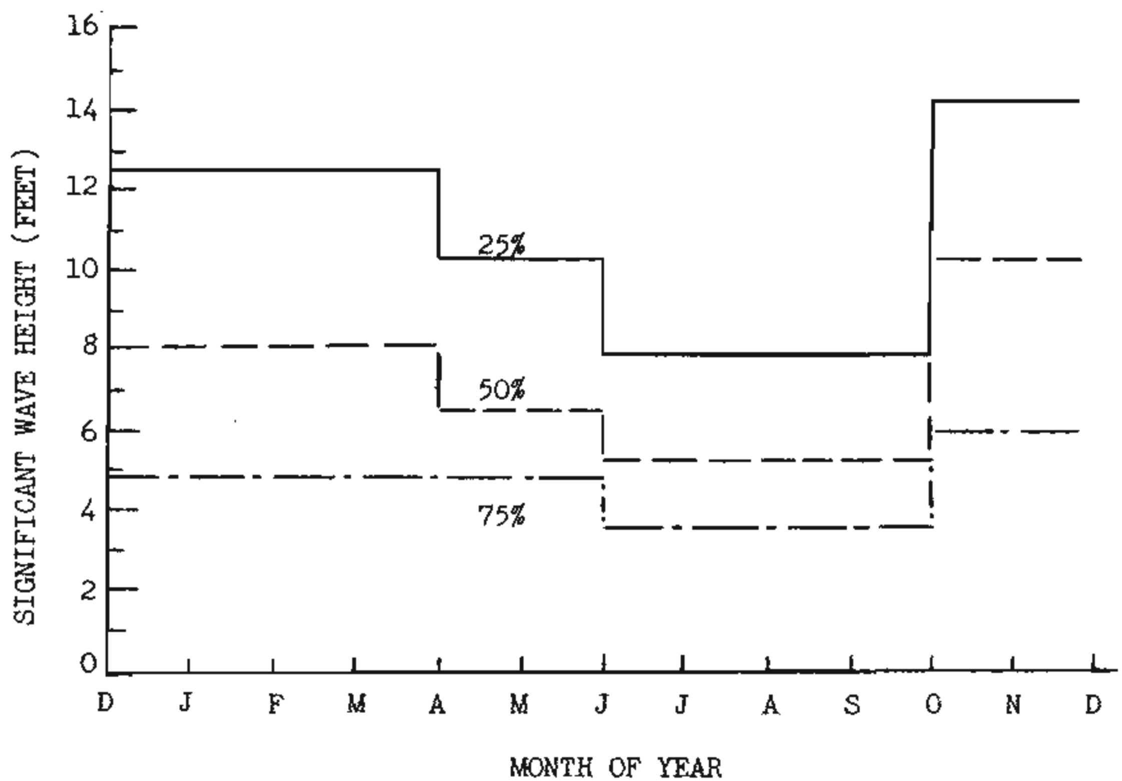
RECURRENCE INTERVAL OF WINDS



Source: Horrer, P.L., 1975, Statement before the U.S. Department of Interior, Bureau of Land Management Hearing on Proposed Oil and Gas Leasing on the Outer Continental Shelf, Northern Gulf of Alaska, Aug. 12-13, 1975, Anchorage, Alaska.

Figure 11

SEASONAL VARIATION OF WAVE HEIGHTS

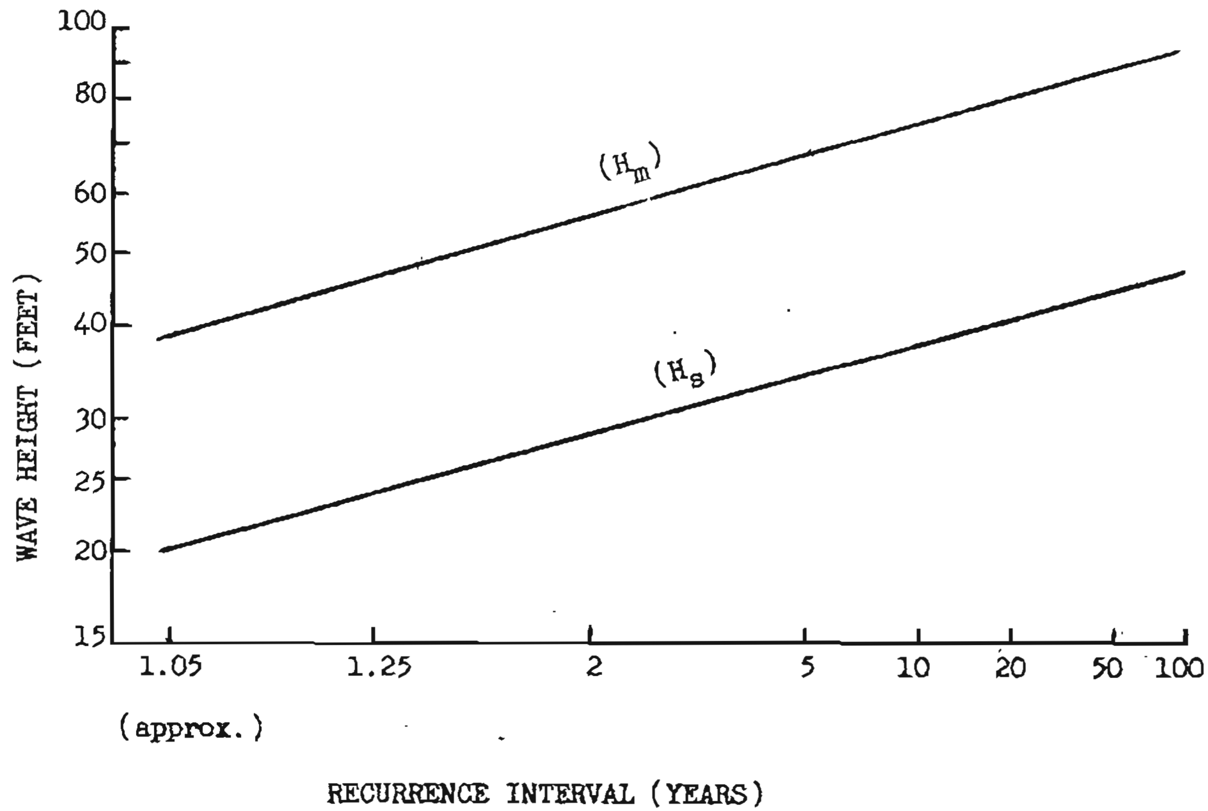


PROBABILITY OF WAVE HEIGHTS ≥ INDICATED VALUE

Source: Horrer, P.L., Statement before the U.S. Department of Interior, Bureau of Land Management Hearing on Proposed Oil and Gas Leasing on the Outer Continental Shelf, Northern Gulf of Alaska, Aug. 12-13, 1975, Anchorage, Alaska.

Figure 12

RECURRENCE INTERVAL OF SIGNIFICANT WAVE HEIGHT (H_s) AND MAXIMUM WAVE HEIGHT (H_m)



Source: Horrer, P.L., 1975, Statement before the U.S. Department of Interior, Bureau of Land Management Hearing on Proposed Oil and Gas Leasing on the Outer Continental Shelf, Northern Gulf of Alaska, Aug. 12-13, 1975, Anchorage, Alaska.

Figure 13

3. Tsunamis associated with large submarine earthquakes must be considered in connection with operations and facilities in the Gulf of Alaska.

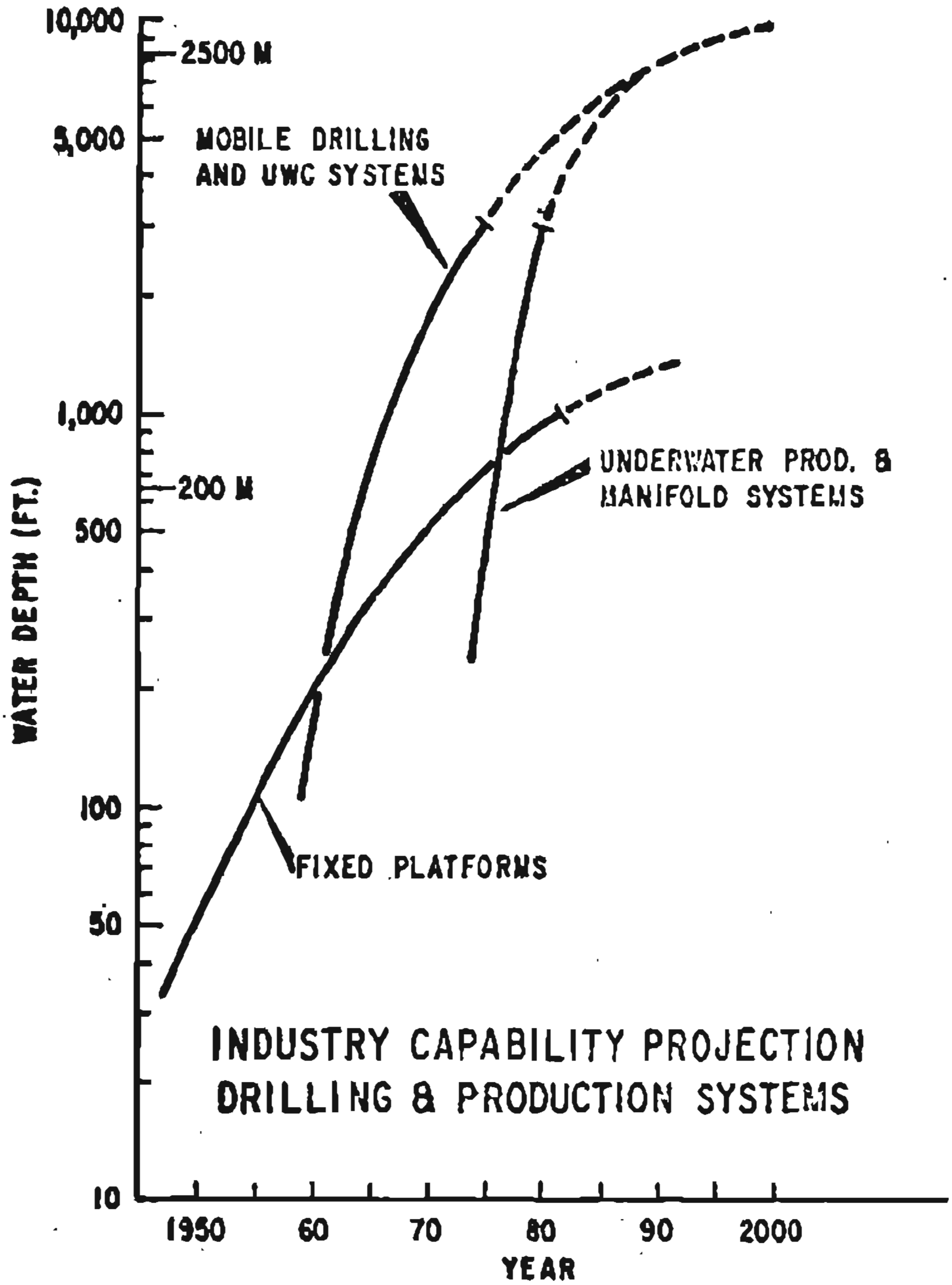
4. Offshore structures in the lease sale areas which appear favorable for oil and gas exploration occur within twelve miles (19.3 km) and as far as 90 miles (144.8 km) from the mainland or Kodiak Island in water depths ranging from 120 feet (36.6 m) to in excess of 1,000 feet (305 m).

5. The Western Gulf of Alaska is isolated and remote from major population centers, industrial areas and from oil supply centers with no significant industrial complex closer than Seattle, Washington. The Western Gulf of Alaska area is more or less undeveloped and would require development of local onshore supply bases, transportation facilities, living areas for workers and families in addition to onshore terminals, storage facilities, and other industrial complexes. There are two deep water ports in the general area, Seward and Kodiak, which are primiarly involved in support of the fishing industry but which would likely be utilized for oil exploration and development in the proposed lease sale area.

6. Sea ice is not a problem in the Western Gulf of Alaska except in isolated bays near glaciers, but ice loading due to surface or superstructure icing (freezing spray) may occur under centain conditions during the coldest winter months and must be considered.

Availability

The availability of technology for offshore oil and gas exploration and production comes from shallow water, near shore operations in moderate climates, into deeper water and more hostile environments. Figure 14 shows the present water depth capability for mobile drilling and underwater well completion systems, underwater production and manifold systems, and fixed



Source: Geer, R.L., 1974, Offshore drilling and production technology - where do we stand and where are we headed: Preprint, American Petroleum Institute meeting, April 9-11, 1974, Denver, Colorado.

Figure 14

platforms with an industry capability projection of drilling and production systems into deeper water in the short term. A summary of present and projected water depths, drilling and production capabilities for various U.S. offshore areas, including the Gulf of Alaska, is shown on Table 2.

The North Sea is an area with severe environmental conditions where oil and gas operations have moved into deeper water utilizing newly developed technology. Comparability of wind and wave conditions indicates that oil and gas technology developed and used in the North Sea may be generally adapted to Gulf of Alaska (figures 15 and 16). In the North Sea area, drilling has been successfully conducted in water depths exceeding 660 feet (200 m) and drilling and production platforms have been placed in 410 feet (125 m) of water. A concrete platform was recently placed in 460 feet (140 m) of water at the Brent Field north of 61° latitude in the North Sea. Large diameter pipelines, 32 inch (81 cm), have been installed successfully in water depths of 480 feet (146 m) and new equipment under construction will extend that capability to deeper water (Rainey, 1974). Existing and planned offshore storage facilities include a one million barrel concrete storage facility on the ocean floor in 230 feet (70 m) of water at the Ekofisk field. Bottom attached floating storage facilities include Shell Oil's SPAR system for the Brent field, Hamilton Brothers floating platform for the Auk field, and concrete gravity base production platforms which include storage of up to one million barrels of oil in the Brent and Beryl fields (Geer, 1974).

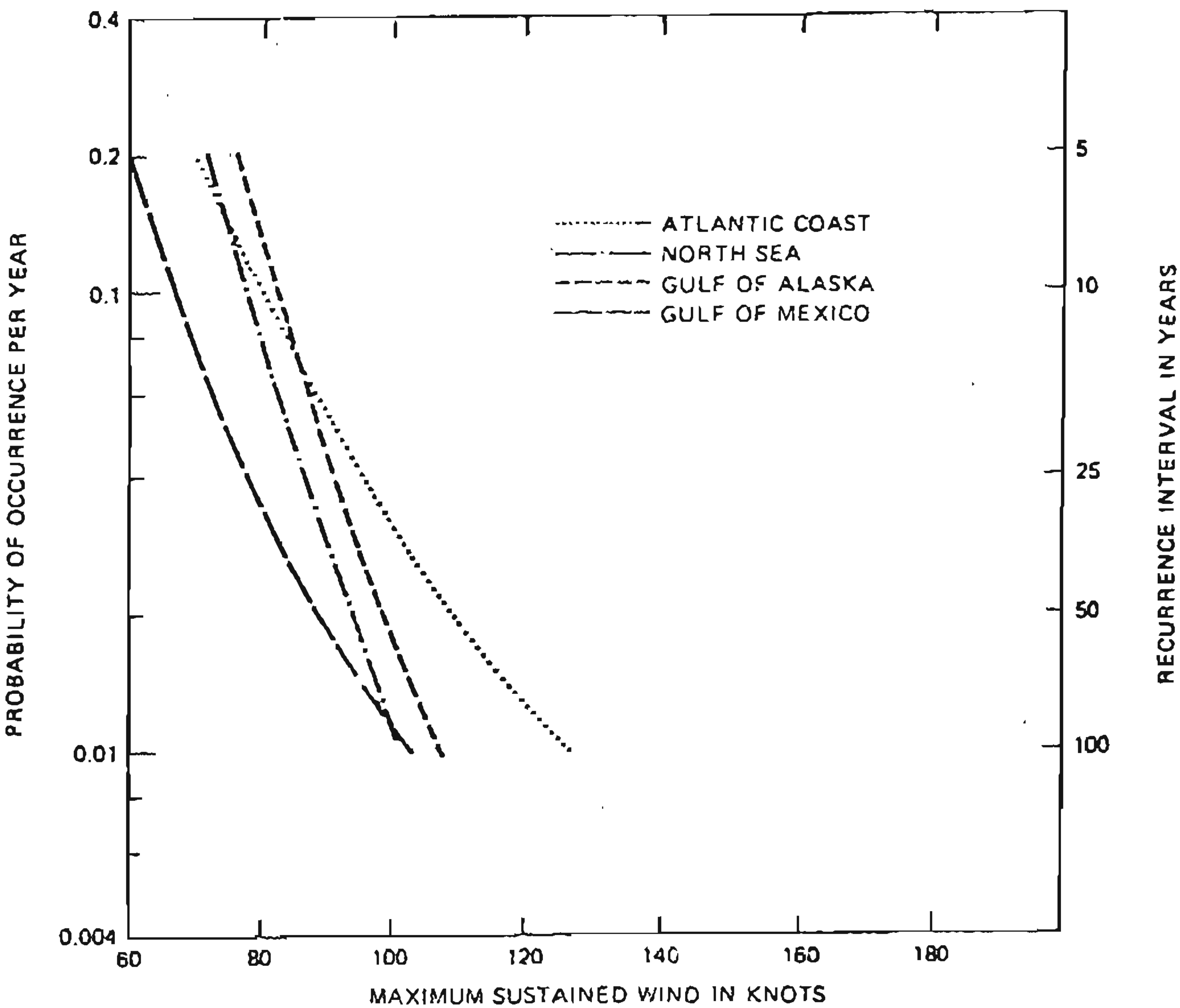
PRESENT AND FUTURE WATER DEPTH CAPABILITIES AND EARLIEST DATES FOR EXPLORATION DRILLING AND PRODUCTION FOR UNITED STATES OUTER CONTINENTAL SHELF AREAS

Area/Province	Maximum Water Depth Capabilities: Exploration Drilling*	Maximum Water Depth Capabilities: Production	Earliest Date: Exploration Drilling	Earliest Date: Production†
1. North Atlantic	At present, jack-ups 300 - 350 feet. Drillships and semi-submersibles 1,000 - 1,500 feet. Dynamically positioned drillships 2,500 - 3,000 feet. In the future, forecast capabilities up to 6,000 feet by 1980.	At present, fixed platforms 600 feet. Under water completions (UWC) 1,200 - 1,500 feet. In the future, platform capability 1,000 feet by 1979 - 1980. UWC 3,000 feet by 1978 - 1980.	Now	Fixed 24 well platform in 600 feet ready for production 4 to 5 years after field discovery and delineation. Pipelines or barges required for production.
2. Middle Atlantic	Same as North Atlantic	At present, fixed platforms 600 feet. UWC 1,200 - 1,500 feet. In the future, platform capability 1,000 feet by 1979 - 1980. UWC 3,000 feet by 1979 - 1980.	Now	Same as North Atlantic
3. South Atlantic	Same as North Atlantic	Same as Middle Atlantic	Now	Same as North Atlantic
4. East Gulf 5. Central Gulf 6. West Gulf	Same as North Atlantic	At present, fixed platforms 1,000 feet. UWC 1,200 - 1,500 feet. In the future, UWC 3,000 feet by 1978 - 1980.	Now	At present, fixed 24 well platform in 400 feet ready for production 3 to 4 years after field discovery and delineation. Fixed 40 well platform in 1,000 feet ready for production 6 to 8 years after field discovery and delineation. In the future, production from UWC in 1,000 - 3,000 feet by mid-1980's. Because of special treating facilities required, sour (H_2S) hydrocarbon production in Area 4 may add 1 to 2 years.
7. Southern Cal. Borderland 8. Santa Barbara 9. North & Central Cal. 10. Washington - Oregon	Same as North Atlantic	For Areas 7 and 8, same as Gulf of Mexico. For Areas 9 and 10, same as North Atlantic.	Now	For Areas 7 and 8, same as Gulf of Mexico. For Areas 9 and 10, same as North Atlantic. Earthquake zones require special surveys and engineering considerations.
11. Cook Inlet 12. Southern Aleutian Shelf 13. Gulf of Alaska 14. Bristol Bay S. of 56° Lat.	Jack-ups 300 - 350 feet. Drillships and semi-submersibles 1,200 - 1,500 feet.	Platforms 600 feet for ice-free areas. For seasonal ice areas such as Bristol Bay and Lower Cook Inlet, platforms to 200 feet feasible.	Now	At present, fixed 24 well platform for ice-free areas in 600 feet ready for production 4 ½ to 6 years after field discovery and delineation; in 200 feet ready for production 4 to 5 years. Earthquake zones require special surveys and engineering considerations that could cause delays. Satellite UWC could extend depth 100 - 200 feet in most areas. In the future, production in ice-free areas in 1,500 feet feasible 1980 - 1985. Production in seasonal ice areas beyond 200 feet feasible 1980 - 1985.
15. Bristol Bay N. of 56° Lat. 16. Bering Sea Shelf 17. Beaufort Sea 18. Chukchi Sea	Jack-ups 300 - 350 feet. Drillships and semi-submersibles 1,200 - 1,500 feet during ice-free periods. Gravel islands and island-type structures 50 feet. Land-fast ice (as in Kotzebue Sound) may be drilled. Conventional offshore rigs not useable in areas of heavy moving ice. Anticipate that current R & D projects such as ice-breaking drillships will extend present capabilities.	Gravel islands and island-type structures 50 feet. Concrete or steel cone structures may be feasible to 200 feet. Drillship capability may permit UWC if latter can be designed for potential bottom ice conditions.	Now, selectively, with some modifications to existing equipment for specific areas.	At present, production from gravel islands and island-type structures 4 to 5 years after field discovery and delineation, provided development drilling from same island as exploration drilling. In the future, development cycle periods for deeper water dependent on current R & D. Additional overland pipelines required for moving petroleum to southern ports, since the pipeline presently under construction will be fully used by projected North Slope production forecasted from current discoveries. Earthquake zones require special surveys and engineering considerations.

* All jack-up rigs derated from indicated maximum water depth capability during severe weather seasons.

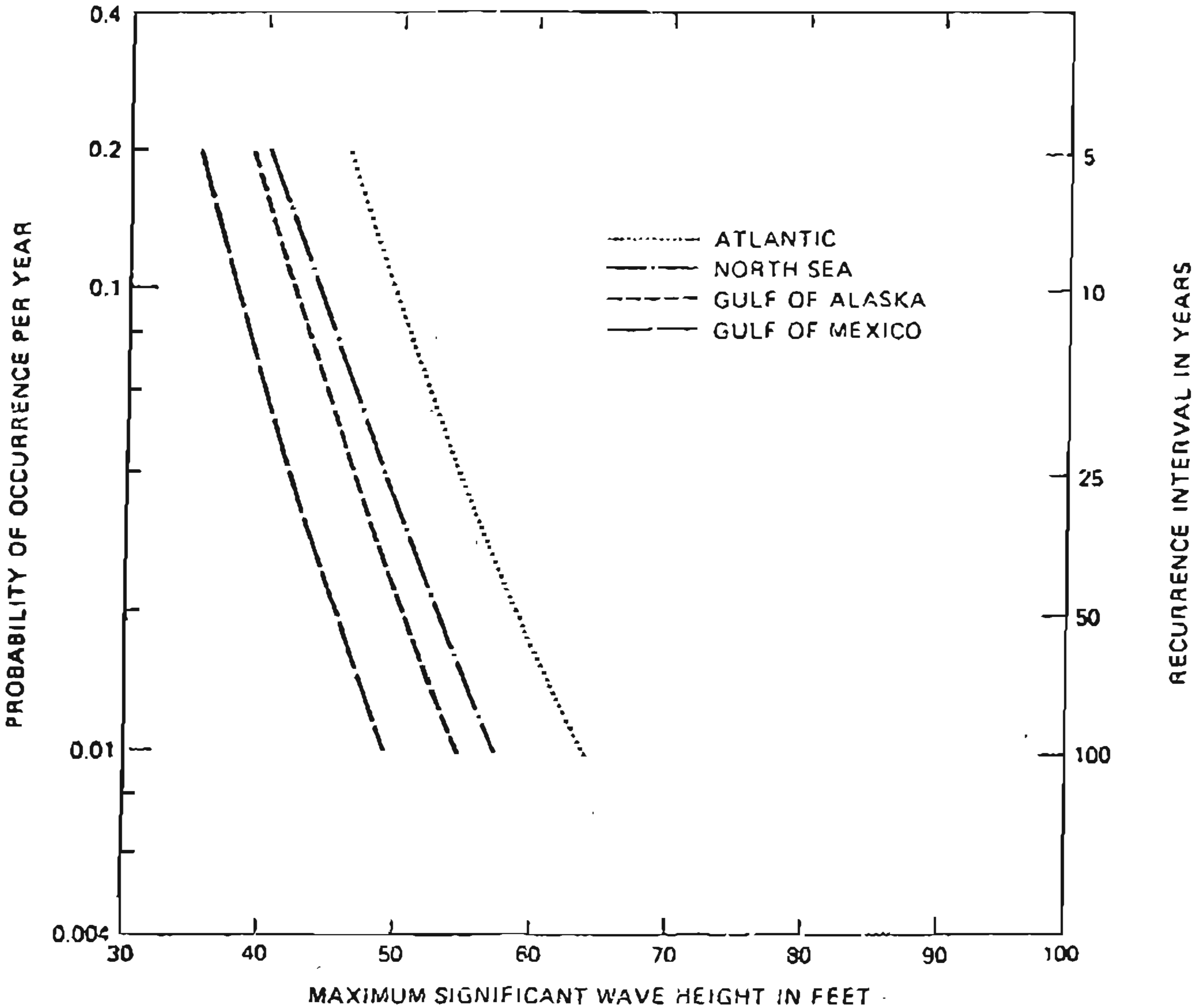
† "Ready for production" assumes all development wells drilled before initial production; one rig per platform. Development period related to number of wells, drilling depth, drilling conditions. Number of wells not limited to examples given.

Source: National Petroleum Council, "Ocean Petroleum Resources", Library of Congress - Catalog Card No. 74-8406, March 1975.



Maximum Sustained Winds for the Atlantic Coast, Gulf of Alaska, Gulf of Mexico, and North Sea.

Source: Tetra Tech, Inc., 1973, "The Effect of Natural Phenomena on OCS Gas and Oil Development", prepared for the Council on Environmental Quality under contract No. EQ4AC010.



Maximum Significant Wave Heights for the Atlantic Coast, Gulf of Alaska, Gulf of Mexico, and North Sea.

Source: Tetra Tech, Inc., 1973, "The Effect of Natural Phenomena on OCS Gas and Oil Development", prepared for the Council on Environmental Quality under contract No. EQ4AC010.

Figure 16

Between 1960 and 1975, 252 subsea wells have been completed worldwide in water depths of 50 - 375 feet (15 - 114 m). Several subsea production systems are in the prototype or test stage for use in water depths of 300 - 1500 feet (91 - 456 m) and are being developed in conjunction with fixed platforms or in areas where platforms are not feasible. Several advanced subsea production systems are being installed or are in use in the Gulf of Mexico and the North Sea.

The type of development in the Gulf of Alaska will depend upon the water depth, distance from shore, the type of oil or gas deposit to be developed and the physical and environmental factors at the discovery location. Shallow water development would likely follow conventional use of fixed steel platforms with pipelines to shore, similar to the Cook Inlet fields, Deep water development may involve: 1) conventional fixed steel platforms as in shallow water or 2) a combination of fixed steel or concrete platforms or structures with subsea wells and production systems and pipelines to shore or 3) one of the two previous production systems utilizing sea floor or floating storage with offshore tanker loading capability.

One well, the Tenneco Oil Company Middleton Island State No. 1, has been drilled offshore in the Gulf of Alaska in approximately 80 feet (24 m) of water utilizing the J. C. MARTHENS, a jack-up rig owned by Sun Marine Drilling Company. Jack-up rigs might be used in water as deep as 300 feet (91 m) in the Gulf of Alaska.

The trend in new drillships and semi-submersible vessels has been toward capability of drilling in deeper water in harsher climates. Most drill ships and semi-submersibles constructed in recent years, and nearly all of those under construction or planned, are of the type designed for extended operations in the rigorous environments of the North Sea, offshore Eastern Canada and the Gulf of Alaska. The semi-submersible rigs are designed for stability under adverse sea and weather conditions whereas the drill ships are designed for maximum mobility and self-sufficiency. Both semi-submersible and drill ships are capable of drilling in water depths of 1,000 ft (305 m) using chain anchor systems. Drill ships with dynamic positioning systems can be used in deeper water. Drill vessels are susceptible to delay during extreme weather conditions, and drilling in the Gulf of Alaska will likely be reduced during the stormy fall and winter season even though the newer rigs are designed for year round operations.

New techniques for evaluating maximum environmental forces and new procedures for evaluating soil characteristics for foundation designs have improved overall reliability of design of offshore equipment.

Drilling Unit Availability

At present, there are two offshore drill vessels in the Gulf of Alaska. The GLOMAR CONCEPTION, a drill ship belonging to Global Marine Inc., is drilling a deep stratigraphic test in OCS waters approximately 29 miles southwest of Yakatage. The GEORGE FERRIS, a jack-up rig owned by Sun Marine Drilling Co., is not drilling at the present and is located in State submerged lands in Kachemak Bay.

There are only two other mobile drilling vessels in the Pacific Coast area; the CUSS No. 1, owned by Global Marine Inc., and the WODECO I, owned by Western Offshore. Both are small floating barge type vessels not designed for long term operations in the Gulf of Alaska.

Twenty-five semi-submersible drilling vessels and drill ships are under construction, or are scheduled for construction on the West Coast of the United States and in the Far East which could be available for drilling in the Gulf of Alaska.

Following is a list of four semi-submersible drilling vessels presently under construction which are contracted for drilling in the Gulf of Alaska or on the West Coast of the United States:

RIG OWNER	SHIPYARD	DELIVERY DATE	CONTRACT
Exxon	Mitsubishi, Japan	March 1977	Exxon, W. Coast and Gulf of Alaska
SEDCO, INC.	Kaiser Steel, Oakland, Calif.	March 1976	Shell, Arco, Mobil Grp. Gulf of Alaska, 2 years
SEDCO, INC	Kaiser Steel Oakland, Calif.	Nov. 1976	Sun, Gulf of Alaska 2 years
Sante Fe	Tacoma Boat Bldg., Washington	Jan. 1976	Amoco - Unassigned 2 years

To obtain offshore drill vessels from other parts of the world will require approximately 200 to 300 days transit time and 1.5 to 5 million dollars since most of them must be moved around South America to Alaska.

A recent offshore mobile rig count showed 298 total units in operation worldwide of which 83 are floating drill ships, semi-submersible vessels, or barges, 139 are jack-up (bottom supported) and 76 are semi-submersible. An additional 139 units under construction or planned, including 33 drill ships, 55 jack-ups and 51 semi-submersibles (Offshore Rig Data Service, 1975).

Table 3 indicates mobile offshore rigs under construction with a breakdown of completion dates through 1977 by rig type.

Manpower

As in the case with drilling units, most of the skilled manpower for exploratory drilling will have to come from other areas. The reservoir of manpower, in general, needed for the drilling, development and production, including the installation of platforms, pipelines and onshore facilities is relatively small due to 1) the low population density in Alaska and 2) the lack of previous large scale petroleum development in the area of the Gulf of Alaska.

Some of the skilled manpower may be available in Alaska, depending on the stage of construction of the Trans-Alaska or other pipelines and of the Prudhoe Bay oil field. As the energy shortage continues, many predict that skilled manpwer for the oil and gas and related industries will be in short supply.

A large potential supply of manpower, available for training, exists in the Pacific Northwest and California. Its real availability will depend in large part on the relative state of the national economy and in finding a sufficient number of individuals willing to work far from home under harsh climatic conditions for long periods of time.

Time Frame For Development

Table 4 showing the most probable time frame for platform development in the Gulf of Alaska was prepared by a subcommittee of the Gulf of Alaska Operators Committee and presented to the Council of Environmental Quality at hearings in September 1973. This projection indicates 2½ years after lease sale until substantial exploratory drilling will occur due to the shortage of suitable drilling vessels and a minimum of seven to eight years until first production and ten years until maximum production. It is possible that the time frame could be accelerated for nearshore areas in shallow water which would be drilled and developed with less difficulty whereas development of production from deep water areas could be delayed due to design and construction for special deep water equipment and facilities.

The expensive operating conditions and the expected high cost of equipment for the Gulf of Alaska may restrict development to the shallow water areas with lower costs and in deeper water, to those fields which have very large recoverable reserves and sufficient potential productivity for economic development.

TABLE 3

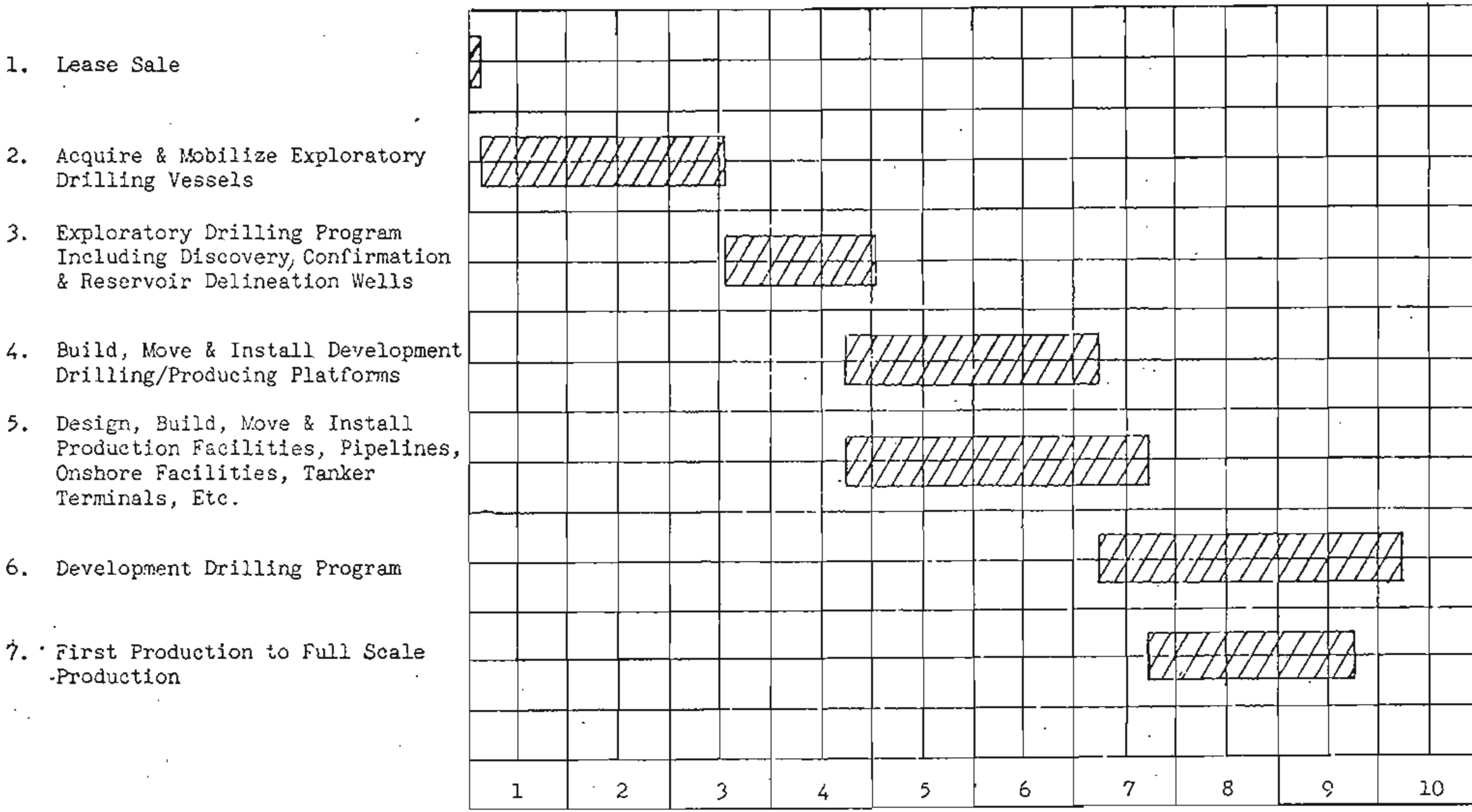
Mobile Rigs Under Construction as of August 1975

Rig Type	Total Number	Completion Rate		
		1975	1976	1977 or later
Semi-submersibles	51	14	33	4
Jackups	55	15	31	9
Drillships	33	9	18	6
Total	139	38	82	19

Source: Offshore Rig Data Service, 1975, The rig locator report: The Sheffer Co., Houston, Texas, August 7.

TABLE 4

MOST PROBABLE TIME FRAME FOR PLATFORM DEVELOPMENT
GULF OF ALASKA



Source: Oceanographic Survey Technical Committee, 1973, Development and production: Section 3 of a 5 part report to the Gulf of Alaska Operators Committee, August, Figure 4.

ACKNOWLEDGEMENTS

The responsibility for specific subjects is as follows: von Huene, structure, deep sea lithology, geologic history, petroleum geology; Smith, technology, time frame, infrastructure for development; Hampton, environmental geology; Moore, lithology of rocks on Kodiak Island, structure, petroleum geology; Dolton, resource assessment. Manuscripts were reviewed by R. Q. Foote, W. F. Hanna, C. D. Masters, M. R. Klepper.

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