A SUMMARY REPORT OF THE REGIONAL GEOLOGY, PETROLEUM POTENTIAL, ENVIRONMENTAL GEOLOGY, AND TECHNOLOGY FOR EXPLORATION AND DEVELOPMENT IN THE AREA OF PROPOSED LEASE SALE 48, CALIFORNIA CONTINENTAL BORDERLAND

By

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SUMMARY

This report reviews geological and technological data pertinent to OCS Lease Sale 48. Under consideration are approximately (54,400 sq. km) 21,000 square miles of the California Continental Borderland north of the U.S.-Mexico boundary. Specifically excluded are the Federal Ecological Preserve and Federal Buffer Zone in the Santa Barbara Channel, parts of Santa Monica and San Pedro Bay, and an area along the southwest extension of the International boundary.

Although the offshore areas proposed for OCS Lease Sale 48 contain sequences of sedimentary rocks comparable to those of adjacent onshore oil-producing areas, there are some significant differences in thicknesses, hydrocarbon content, age, and depth of burial of the strata. Geologic structures, in general, seem to be similar in size and origin throughout the borderland. Some of the requirements necessary for large petroleum accumulations seem to be absent in much of the offshore region. Apart from the nearshore basins and the Santa Rosa-Cortes Ridge, the sedimentary rock sequences are relatively thin; and over large areas of the borderland, Miocene strata presumably rest directly on basement rocks or have been truncated to expose early Tertiary strata. Thick late Tertiary turbidite sands, that have produced prolific amounts of oil onshore, are not expected to be widespread in basins seaward from the nearshore islands. Based on organic geochemical analyses, offshore Miocene strata contain good to excellent potential source rocks, but most sampled early Tertiary strata contain insufficient organic matter to be considered good potential source rocks. However, the deep stratigraphic test well drilled on Cortes Bank penetrated potential source

rocks of late Eocene age. Organic matter from the Tertiary section of this well and from Tertiary samples along the banks and ridges, is immature, indicating shallow burial and a thermal regime ordinarily considered too low for the generation of petroleum. Sandstone beds of early Miocene and Eocene age penetrated in the test well have porosities that are within the range of those of good reservoir rocks. Even though more than 5,000 feet (1524 m) of Upper Cretaceous strata were penetrated in the well, reservoir-quality rocks are absent, and source rock potential is low. Fractured Miocene shale reservoirs, both in the deeper basins and on the down-flank margins of major uplifts are prospective targets. Because the early Tertiary depositional history of the borderland is as yet poorly understood, large areas may contain undercovered shallow-water sands of reservoir quality. Although seeps are common onshore and in the Santa Barbara Channel, well documented oil seeps have not been reported seaward of the islands.

Petroleum resources for the proposed sale areas are estimated in aggregate at probability levels of 5 percent and 95 percent and are based in part upon volumetric and analog methods. The following amounts of oil and gas resources that could be recovered under present conditions of economy and technology are:

	95 Percent Probability	5 Percent Probability	Statistical Mean
Oil (billions of barrels)	1.9	5.8	3.6
Gas (trillions of feet^3)	2.2	6.3	3.9

Effects of active seismicity, seafloor instability, sediment erosion, subsidence susceptibility, and hydrocarbon seeps should be given careful consideration as potential environmental hazards. Unstable ground and active faults are evident along ridge and shelf areas throughout the borderland.

The northern slope of Santa Barbara Channel, the western flank of Santa Rosa-Cortes Ridge, and the eastern edge of the San Diego Trough are particularly susceptible to slumping. Inundation of coastal lowlands and future installations on offshore banks possibly could result from both locally generated and external tsunamis. Sparse sediment cover and abundant rocky outcrops devoid of sediment along the shallow areas of the Santa Rosa-Cortes Ridge attest to strong current action along the ridge.

Technology for offshore petroleum exploration and development requires a variety of operations and installations including geological and geophysical surveys, drilling, platforms, possible subsea completion systems, separation and treatment units, pipelines, storage containers, reservoir stimulation and secondary recovery programs. Regulations for exploratory drilling are in effect, and specifications for other operations and installations are under study.

Because the cost increases with water depth and because operations could be more than 100 miles (161 km) from the mainland, construction of some pipelines would be economically prohibitive. Presently available equipment can lay large diameter (36") pipe in water depths as deep as 600 feet (183 m), but there are large expanses within the proposed lease sale area that are in much deeper water. Barges and tankers are a likely alternative. Oil storage and treatment installations could include both seafloor and floating facilities.

Although present exploratory drilling is limited to shallow and intermediate water depths, drilling capability in water as deep as 6,000 feet (1829 m) is forecast by 1980. Fixed platforms now can be set in 1,000 feet (305 m) of water and underwater completions (UWC) in 1,500 feet (457 m). By 1980, UWC may attain 3,000-foot (914 m) depths. Available (July 1, 1976) drillships in California are CUSS I, capable of drilling to 16,000 feet (4877 m) in 600-foot (183 m) water depths, GLOMAR CORAL SEA, capable of drilling to 25,000 feet (7620 m) in 1,500-foot (457 m) water depths, and the semi-submersible, OCEAN PROSPECTOR. Within a short time, three or four drilling vessels from other parts of the world are expected to explore Sale 35 leases.

The physical environment of the southern California OCS is relatively benign in comparison to that of the North Sea and Alaska. Siting of installations may present problems with respect to weather, topography, water depth, and seismicity, but these can be surmounted with proper engineering-design criteria. Currently, manpower and capital are accessible, provided the necessary incentives are derived from exploratory drilling on tracts of OCS Lease Sale 35. It seems likely that the most attractive shallow-water tracts will be tested within 2 years of the lease sale and that initial production could begin 3 to 5 years after the sale. Maximum production from optimum tracts would be expected 5 to 8 years after the sale.

INTRODUCTION

This report is a brief summary of the regional geologic framework petroleum potential, environmental geology, and operational considerations that will affect exploration and development in the proposed area OCS Lease Sale 48. The information used in preparation of this report is all publicly available. Coverage ranges from detailed, closely spaced surveys in local nearshore and island areas to broad reconnaissance of parts of the region far offshore (Attachment A).

The proposed sale area of approximately 21,000 square miles (54,400 sq km) falls within the California Continental Borderland north of the United States-Mexico boundary and north of 32° lat. (fig. 1).

The Summary and the section entitled Regional Geologic Framework were written by J. G. Vedder. The section on Petroleum Geology was prepared by J. C. Taylor and the Petroleum Resource Appraisal section by E. W. Scott. Geologic Hazards are described by H. G. Greene. Staff of the Conservation Division compiled the section on Operational Considerations.

REGIONAL GEOLOGIC FRAMEWORK

General Setting

Proposed OCS Lease Sale 48 lies offshore from the structurally complex part of California that includes the western Transverse Ranges province and the northern Peninsular Ranges province. This offshore region commonly is referred to as the borderland of southern California. The geologic evolution of the region is attributed to tectonic instability of the continental margin along the boundary between the Pacific and North American plates. As a result of right-lateral shear, which began along the plate boundary about 30 m.y. ago, a network of ridge-and-basin structures developed. Rapid erosion of the ridges and thick accumulation of sediment in the basins accompanied by volcanism began about 20 m.y. ago. Subsequent deformation in response to continued right shear, which resulted in the formation of local en echelon zones of folds and faults, began about 12 m.y. ago and is continuing today.

As shown in figure 1, the proposed lease sale area is divided into three regions: the Santa Barbara Channel, the inner basins and banks, and the outer basins and banks.

page 6 is fig. 1

Santa Barbara Channel. The geologic framework of Santa Barbara Channel is described by U.S. Geological Survey (1975) and Campbell and others. Basement rocks similar to some types of the Coast Range Franciscan have been penetrated in the Union Gherini No. 1 well on the east end of Santa Cruz Island, north of the Santa Cruz Island fault, where greenstone was cored and dated at 152 ± 8 m.y. (Howell, McLean, and Vedder, 1976). Exposed basement rocks south of this fault are described in the chapter on the outer basins and banks.

Sedimentary rocks range in age from Late Cretaceous to Holocene (fig. 2). The only reports of Cretaceous sedimentary rocks beneath the Santa Barbara Channel are from exploratory wells drilled near the middle of the channel (Vedder and others, 1969; Weaver, 1969). The Richfield Santa Cruz No. 1 well, located at the west end of Santa Cruz Island and north of the Santa Cruz Island fault, drilled 2,000 feet (610 m) of conglomerate, sandstone, and shale of Late Cretaceous age (Weaver, 1969; Howell, McLean, and Vedder, 1976). The Richfield Santa Cruz No. 2 well, located south of the fault, penetrated 2,260 feet (689 m) of sedimentary rocks of similar age and lithology. A recent exploratory well drilled by Mobil south of the median fault on Santa Rosa Island spudded in Eocene strata and presumably bottomed in Cretaceous rocks.

Paleogene rocks beneath the channel are believed to underlie most of the offshore region and to attain thicknesses of as much as 10,000 feet (3048 m) or more nearshore (Curran, Hall, and Herron, 1971; Campbell and others, 1975). Marine sandstone and claystone beds form the bulk of the Paleocene and Eocene sequences and locally are interlayered with conglomerate. The Oligocene section grades westward from nonmarine to marine and is composed primarily of sandstone and siltstone (Curran, Hall, and Herron, 1971; Vedder and others, 1974).

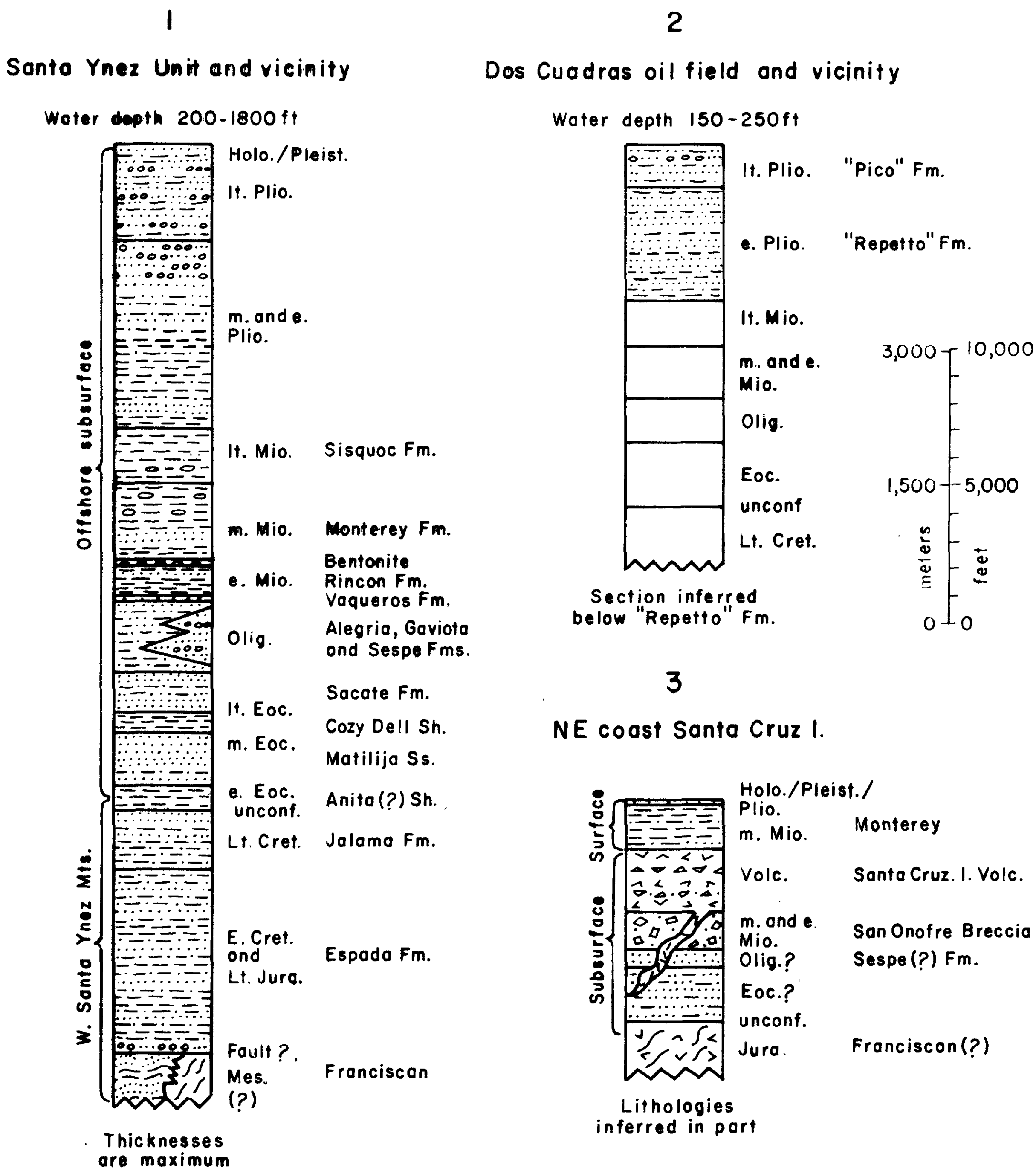

Fig. 2. Stratigraphic columns, Santa Barbara Channel region. Provincial chronologies and named stratigraphic units are shown to the right of each column. The lithologies, where known, are generalized.

Neogene strata in the Santa Barbara Channel region are composed of diverse sedimentary rock types and locally interlayered volcanics. In general, the early Miocene section is composed of mudstone, sandstone, and conglomerate; the middle Miocene, siliceous and calcareous shale; and the late Miocene, claystone and siltstone. Stratigraphic units of all ages, however, are typified by facies changes; and volcanic intrusives, flows, and pyroclastics interrupt the early and middle Miocene sequences, particularly along the southern edge of the region (Dibblee, 1950, 1966; Weaver and others, 1969; Howell, McLean, and Vedder, 1976; McLean, Howell, and Vedder, 1976). Pliocene strata in the northeastern part of the channel include turbidite sequences of sandstone, mudstone and conglomerate that are as much as 12,500 feet (3810 m) thick near Ventura and 6,000 feet (1829 m) thick in mid-Channel south of Santa Barbara (Curran, Hall, and Herron, 1971). The Pliocene section thins westward and wedges out southward.

Quaternary sediments, that onshore grade eastward from marine to nonmarine, are more than 4,000 feet (1219 m) thick directly offshore from Ventura (Campbell and others, 1975). These strata are composed chiefly of semi-consolidated sandstone and conglomerate together with minor amounts of siltstone.

Repeated tectonism throughout late Cenozoic time has left a complex imprint on older structures in the Santa Barbara Channel region. Most faults and folds are oriented east-west as they are in the onshore parts of the western Transverse Ranges province (Vedder, Wagner, and Schoellhamer, 1969; Campbell and others, 1975). Folds occur in well defined trends, and individual anticlines commonly are arranged en echelon. High-angle faults with apparent normal and reverse separations are interspersed with those that have strike-slip components of movement (Lee and Vedder, 1973; Ellsworth and others, 1973; U.S. Geological Survey, 1975; Greene, 1976). Some old structures may have controlled sediment dispersal as early as Eocene time, and many faults cut strata no younger than Miocene. On the other hand, domed late Pleistocene alluvium, tilted marine terrace platforms, and faults that cut Holocene seafloor sediments attest to the youthfulness of tectonic activity, particularly along the mainland edge of the channel.

Borderland, inner basins and banks--The region that extends southeastward from Anacapa Island and Hueneme Canyon to the Mexican border and that lies inboard from the crests of Santa Cruz-Catalina Ridge and Thirtymile Bank contains at least three large basins, each of which has had a somewhat different geologic history. The Santa Monica and San Pedro Basins seem to be floored by Miocene volcanic rocks and/or schist basement with little or no strata beneath the volcanics (Junger and Wagner, in press). The Gulf of Santa Catalina and San Diego Trough probably are underlain by Peninsular Ranges basement rocks along their easternmost edges and by schist and volcanics elsewhere (fig. 3). Unlike the western edges, where Miocene strata apparently overlie Catalina Schist and volcanic rocks, as at Thirtymile Bank, the eastern edges contain Upper Cretaceous and Paleogene strata, as on the San Diego shelf.

In the deep northwestern part of the Santa Monica Basin, as much as 8,000 feet (2438 m) of latest Miocene, Pliocene and younger sedimentary rocks may have accumulated above the volcanics. Along the northeast slope, Miocene strata composed chiefly of shale are as thick as 2,600 feet (792 m) and along the southeast flank of the basin, they are 1,300 to 1,800 feet (396-549 m) thick. On the north edge of San Pedro Basin, the Miocene sedimentary section rests on schist and volcanics and is estimated to be 3,000 feet (914 m) thick (fig. 3). This section seems to thin basinward (southwestward) and is not present beneath the central deep or on parts of the southwest flank of the

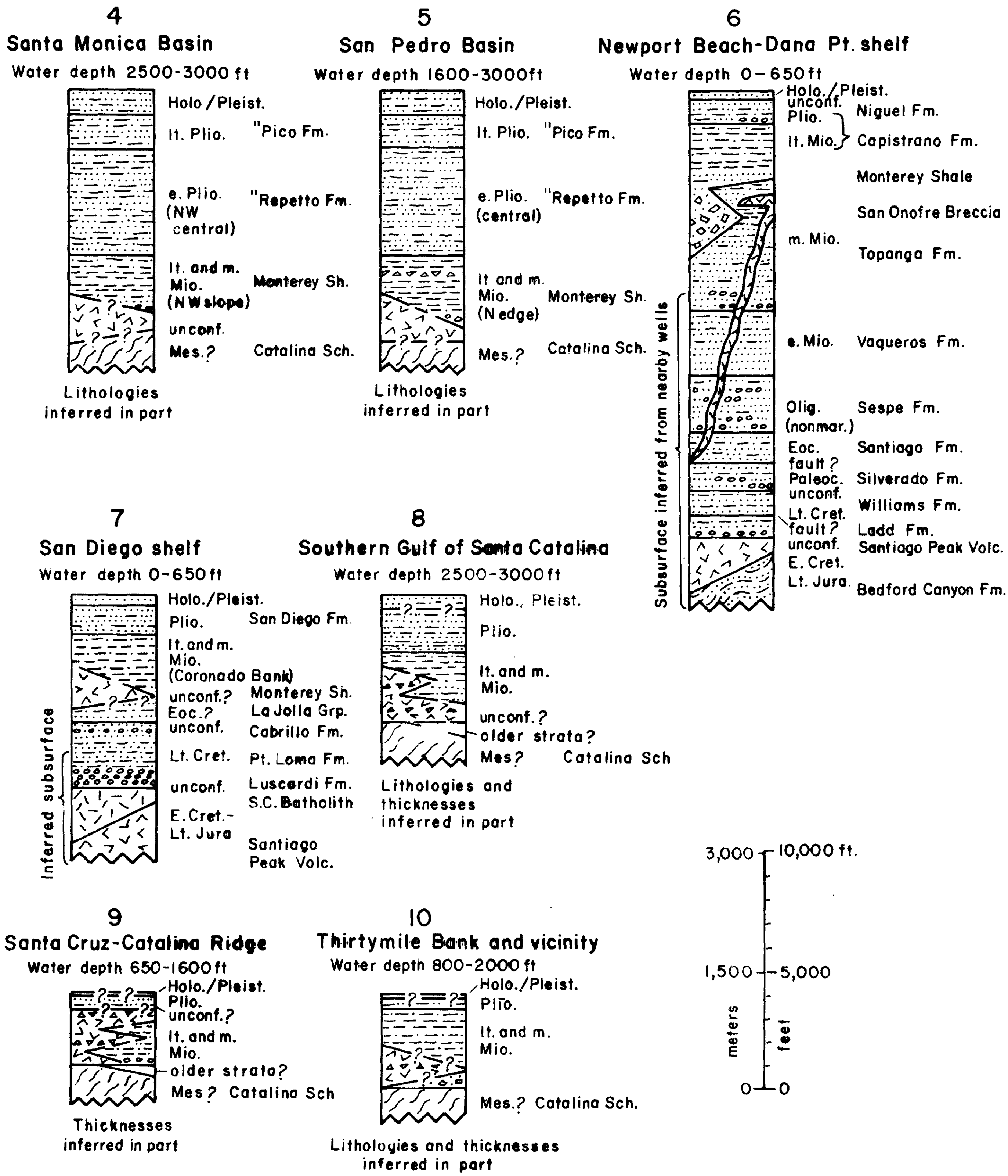

Fig. 3. Stratigraphic columns, inner basins and banks. Provincial chronologies and named stratigraphic units are shown to the right of each column. The lithologies are generalized and inferred where noted.

basin. As much as 7,000 feet (2134 m) of Pliocene strata are believed to overlie volcanic rocks and/or schist basement in the central part of the San Pedro Basin (Junger and Wagner, in press).

In the nearshore shelf area east of the offshore extension of the Newport-Inglewood fault zone (fig. 4), Upper Cretaceous and Paleogene strata consisting chiefly of sandstone, conglomerate, and mudstone unconformably overlie crystalline basement rocks. Near Laguna Beach this pre-Miocene stratigraphic sequence is more than 7,000 feet (2134 m) thick in the subsurface section; and in the vicinity of San Diego, approximately equivalent strata are estimated to have a maximum thickness of 5,000 feet (1524 m). Nearly 11,000 feet (3353 m) of Miocene sandstone, shale, conglomerate, and breccia beds underlie the shoreline area between Newport Beach and Laguna Beach, but equivalent strata offshore from San Diego are thin or completely eroded. Pliocene siltstone and sandstone units with minor conglomerate lenses are as much as 1,000 feet (305 m) thick east of Dana Point and about 1,250 feet (381 m) thick at San Diego. Relatively thin sequences of Miocene shale interlayered with volcanic flows are overlain by Pliocene silts and sands that locally may be as much as 4,000 feet (1219 m) thick beneath the central Gulf of Santa Catalina and 2,000 feet (610 m) thick beneath the San Diego Trough.

The structure of the inner basins and banks is complex; folds near the mainland coast along the seaward extension of the Newport-Inglewood fault zone are comparatively small and steep-flanked, and faults occur both as zones of en echelon breaks or as single traces. Most folds and faults are oriented northwest (fig. 4). Some large anticlinal structures such as Coronado Bank are broad and nearly symmetrical but little is known about their development. Faults range in age from middle Miocene to Quaternary and presumably include

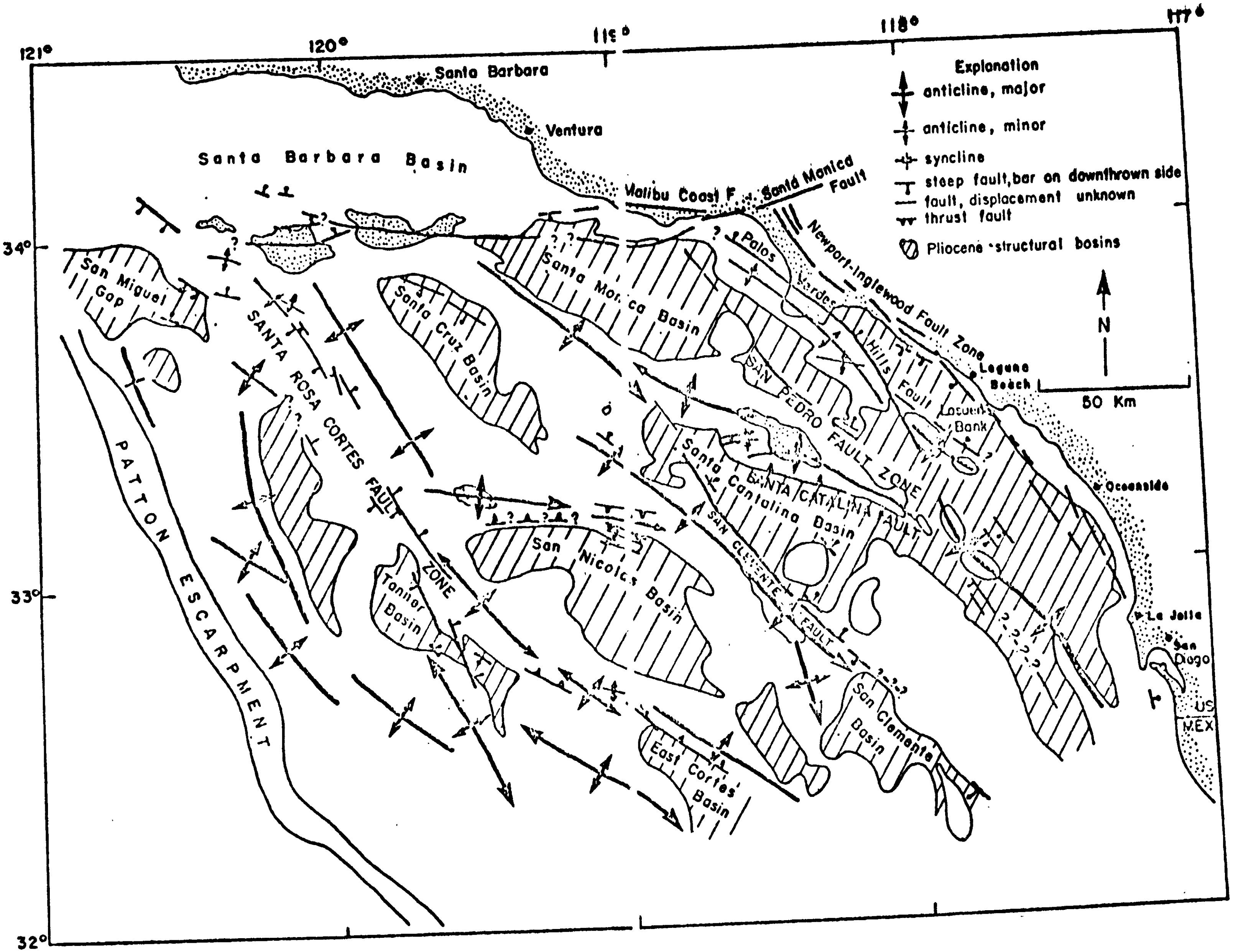

Fig. 4. Tectonic map showing major structural trends and basins south of the Santa Barbara Chann:l (from Junger, 1976).

those with strike-slip as well as dip-slip separations. The age of the small folds probably is restricted primarily to post-late Miocene to pre-late Pleistocene time.

Borderland, outer basins and banks--Low-grade metamorphic rocks that presumably are related to those exposed on and around Santa Catalina Island and in the Palos Verdes Hills have been sampled at numerous localities within the borderland south of the northern group of Channel Islands and west of Santa Catalina Island and the San Diego Trough. Lithic wacke and argillite similar to Coast Range Franciscan and "Knoxville" rock types recently were dredged southeast of San Nicolas Island, west of Tanner Basin, and from the northern Patton Ridge. Schistose rocks that resemble the Catalina Schist form the crest of a low, northwest-trending ridge about 5 miles southwest of Santa Rosa Island. Serpentine and metamorphosed ultramafic intrusive rocks much like those on Santa Catalina Island were recovered from the northern Patton Escarpment and from the saddle on the ridge between Santa Barbara Island and San Clemente Island. On Santa Cruz Island, south of the median fault, greenschist-facies rocks of the Santa Cruz Island Schist are intruded by plagiogranite and diorite that has been dated at 145 ± 5 m.y. The distribution of these various types of rocks beneath the borderland is unknown.

South of the northern group of Channel Islands, large seafloor outcrops of Cretaceous strata are not known with certainty, and Lower Cretaceous samples have not been reported. Inasmuch as Upper Cretaceous strata were penetrated in wells on Santa Cruz Island, they probably are present in the subsurface section immediately south of the island. Redeposited Cretaceous nannofossils in Miocene strata on the northern part of the Santa Rosa-Cortes Ridge directly south of Santa Rosa Island, support the inference that Cretaceous strata were being subjected to erosion in Miocene time in that area. It seems likely that an Upper Cretaceous sedimentary section underlies Eocene strata on the San Nicolas Island platform. From there, these strata probably continue southeast beneath the Santa Rosa-Cortes Ridge as far as Cortes Bank, where nearly 4,000 feet (1219 m) of Late Cretaceous turbidites (fig. 5) were penetrated in a deep stratigraphic test well (OCS-CAL 75-70 No. 1). Cretaceous sedimentary rocks also are present in the vicinity of Nidever Bank and on the northern end of Garrett Ridge. Although equivalent strata possibly underlie parts of the Patton Ridge, their presence there has not been documented by our sampling.

Lower Tertiary rocks are rather sparsely distributed as seafloor outcrops on the outer borderland. Paleocene strata occur on the northwesternmost part of the Santa Rosa-Cortes Ridge and may be exposed on the shelf west of San Miguel Island. Beds of Eocene sandstone and claystone are present on the platform west of San Miguel Island, and the broad shelf around San Nicolas Island is underlain by interbedded sandstone and siltstone units of Eocene age that extend northwest beyond Begg Rock. Correlative strata undoubtedly constitute a thick subsurface section southward from Santa Rosa Island. Oligocene sandstone and mudstone beds are exposed on Cortes and Tanner Banks and at places along Patton Ridge.

The distribution of Eocene rocks in the subsurface section of the outer part of the borderland is not known with certainty, but we infer that strata of this age underlie younger rocks beneath most of the Santa Rosa-Cortes Ridge northwest of San Nicolas Island, where they may range from 4,000 to 7,000 feet (1219-2134 m) thick, and they extend under much of the same ridge southeast beneath Dall Bank to Tanner and Cortes Banks. Equivalent rocks underlie both Santa Cruz and San Nicolas Basins (fig. 5), and they thin eastward and wedge out near the eastern edges of these basins. Even though they have been sampled no farther south than Cortes Bank, it seems likely that Paleogene strata extend southeastward of that area. Because wedge-outs, pre-Miocene erosion, and fault truncation may have occurred along the west edge of Blake Knolls and Sixtymile Bank, the Paleogene strata are missing and basement rocks are exposed. Early Tertiary strata have not been reported from the ridge system that extends southeastward from Santa Cruz Island to Sixtymile Bank or from the basins and banks directly east of it. However, intruded remnants of Paleogene or Upper Cretaceous siltstone, sandstone, and conglomerate recently have been found near the southeast end of Santa Catalina Island.

Much of the crest of the Santa Rosa-Cortes Ridge southward from Santa Rosa Island and northward from Begg Rock is composed of silty claystone of early Miocene age. Strata of the same age and similar composition are present on the shelf west of San Miguel Island and in the vicinity of Tanner and Cortes Banks. Correlative sedimentary rocks presumably blanket most of the Santa Rosa-Cortes Ridge, southeast of the San Nicolas Island salient and underlie the Patton Ridge and intervening basins. Sandstone of possibly early Miocene age occurs at Sverdrup Bank, Dall Bank, and the Cortes-Tanner Banks area.

Fine-grained strata of middle Miocene age, predominantly shale and claystone, form large expanses of the Santa Rosa-Cortes Ridge southeast of Santa Rosa Island and between San Nicolas Island and Santa Tomas Knoll. Shaly beds of the same age occur on the shelf west and northwest of San Miguel Island, on Santa Tomas and Shepard Knolls and on Garrett and Patton Ridges. Diatomaceous shale of middle and late Miocene age is locally present on and around San Clemente Island, in the vicinity of Santa Barbara Island, and at Santa Catalina Island. Coarse-grained sedimentary rocks of middle Miocene age seem to be sparse seaward of the mainland and northern island shelves. Strata of late Miocene age, chiefly diatomaceous mudstone, have approximately the same distribution along the outer ridges as the middle Miocene and are inferred to drape the slopes and pass beneath younger sediments that floor the outer basins.

Thicknesses of these Miocene sedimentary sequences may range from less than 1,000 feet (305 m) on the ridges to as much as 3,500 feet (1067 m) in some of the larger outer basins. Some of the thinnest sections of Miocene strata are believed to be in the Catalina Basin and in the region of Thirtymile and Fortymile Banks, where volcanic and basement rocks are inferred to be close to the surface.

One of the commonest rock types on the borderland is volcanic rock, most of which is believed to be early and middle Miocene in age. Because these igneous rocks represent diverse conditions of emplacement ranging from aquagene tuffs and thick, extensive flows to local narrow, near-vertical intrusions and sill-like bodies, it is difficult to predict their volume and distribution. They are widespread along Santa Cruz-Catalina Ridge and San Clemente Ridge and around Santa Barbara Island and Fortymile Bank. Volcanic rocks are not as abundant on the Santa Rosa-Cortes Ridge to the west, although they form Northeast Bank and parts of Cortes and Tanner Banks. Along the Patton Ridge-Patton Escarpment, volcanics have been dredged at a number of sites, but their distribution is uncertain.

Exposures of Pliocene sedimentary rocks are much less common than Miocene strata on the outer borderland shelves and slopes and seem to be restricted primarily to the deep basins. Seaward of the islands, Pliocene strata have been recorded at only a few places in water less than 1,500 feet (457 m) deep. Estimates of thickness range from close to 2,000 feet (610 m) in the central parts of Santa Cruz and San Nicolas Basins to less than 500 feet (152 m) on the flanks. Thicknesses of Pliocene strata in the Catalina Basin generally are less than 1,000 feet (305 m) in contrast to an estimated 3,000 feet (914 m) of Pliocene section in a partly filled basin WNW of San Nicolas Island. The predominant rock types among Pliocene samples are semiconsolidated mudstone, unconsolidated mud, and minor amounts of sand. Redeposited sediment in the form of slumped material or turbidite derived from adjoining ridges, banks, and islands probably is present in the Pliocene sections of many of the basins.

Faults on the outer borderland show different kinds of slip and have varying ages. The dominant trend is northwest, but there are two conspicuous east-west zones; one in the vicinity of the northern group of Channel Islands, and the other south and east of San Nicolas Island (fig. 4). Strike-slip separation is indicated on some, such as the San Clemente fault; normal offset by most, and reverse, such as indicated by the curved fault along the saddle between Santa Cruz and San Nicolas Basins. The ages of movement include pre-Pliocene, as on the large northwest-trending fault along the east-central Santa Cruz Basin, but more commonly they are Pliocene and Quaternary. Pre-middle Miocene thrust faults are inferred in the basement rocks of Santa Catalina Island.

In general, large anticlines trend west-northwest at angles oblique to the major fault zones and at places seem to be arranged en echelon. Many are very large, symmetrical, and have low dips on their flanks. Examples are those that underlie Tanner Bank and the San Nicolas Island platform. Along major upwarps such as the Santa Rosa-Cortes Ridge, numerous small folds are superimposed on the larger feature but seem to die out basinward. In many places, topographic highs reflect anticlinal structures. Broad downwarped structural lows form both Santa Cruz and San Nicolas Basins. Some anticlines deform sediments as young as Pleistocene as in the central San Nicolas Basin; others probably are as old as early Miocene, as the main anticlinal structure on northwestern Santa Rosa-Cortes Ridge, where Miocene strata truncate Paleogene strata on both limbs. An unconformity between middle and late Miocene sequences on the flanks of central Santa Rosa-Cortes Ridge suggests local deformation at the end of middle Miocene time.

PETROLEUM GEOLOGY

Distribution and Characteristics of Petroleum in Adjacent Developed Areas

The offshore areas in proposed OCS Lease Sale 48 are adjacent to the two largest petroleum basins in the California coastal province west of the San Andreas fault. The borderland south of 34°N latitude has an inner basin area that is, in part, an extension of the Los Angeles basin. The Santa Barbara Channel between 34° and $34^{\circ}30'$N latitude is the offshore continuation of the Ventura basin. These and other offshore basins, however, each have different stratigraphic and structural characteristics.

As of January 1, 1975, the cumulative production from all onshore California coastal basins totaled 9.9 billion barrels of oil (11.8 billion barrels of oil + gas expressed as BOE [Barrels of Oil Equivalent]). The remaining oil reserves, plus indicated reserves, from proved fields are estimated at 2.3 billion barrels (API, 1975). Production from the coastal basins is more than half of all the petroleum found in onshore California. According to Taylor (1976), the distribution of these resources decreases from south to north as follows: Los Angeles basin (6.7 billion bbls.); Ventura basin (2.0 billion bbls.); Santa Maria (0.6 billion bbls.); Cuyama (0.3 billion bbls.); and Salinas and the north coastal basins (0.3 billion bbls.). Petroleum is concentrated in young reservoirs with 87 percent from late Miocene or younger rocks, 5.3 percent from middle Miocene, 4.7 percent from early Miocene, 2.8 percent from Oligocene, and 0.2 percent from Eocene strata. In each of the basins, most of the known petroleum occurs in a few fields. Five giant fields account for over 52 percent of all the petroleum produced from these basins, and 24 fields, each with cumulative production greater than 75 million barrels, account for over 86 percent (8.5 billion bbls. of oil). Approximately 80 percent of the petroleum is from turbidite sandstone reservoirs, 10 percent from shallow-water sandstone, 5 + percent from fractured siliceous shale, and 5 percent from nonmarine sandstone and conglomerate beds and fractured schist basement. Most of the fields are in faulted anticlinal traps of post-Miocene age; a few are in homoclines against major faults. Only two fields (of those larger than 20 million bbls.) are stratigraphic traps; both are in the Santa Maria basin.

The Ventura basin and its seaward extension, the Santa Barbara Channel, produce from reservoirs of Eocene through Pleistocene age. Total production amounts to 2.0 billion barrels of oil (2.6 billion barrels oil + BOE). It is the only basin that now produces in the Federal OCS of the Pacific Coast. The basin differs from both the Santa Maria and Los Angeles basins in that a thick section of Upper Cretaceous and lower Tertiary beds underlies younger strata. These older rocks are believed to contain the source beds for the dry gas in this basin and to account for the high gas-oil ratios that are nearly twice as high as in other California basins (Taylor, 1976). Furthermore, almost all of the petroleum in the coastal basins from Eocene and Oligocene reservoirs is from the Ventura basin, but this amounts to only 0.35 billion barrels oil plus gas as BOE. Over half of all production in the basin has come from an anticlinal trend over 25 miles long that includes the Ventura field on the east and the Dos Cuadras field in the Federal OCS to the west. Most of the production from this structural trend is from turbidite sandstone reservoirs of early Pliocene age.

The Los Angeles basin has produced 66 percent of the petroleum in the California coastal basins. The source of this oil is believed to be the thick, organically rich Miocene and younger strata that extend throughout most of the basin. Eight of the ten largest fields in the coastal basins are in the Los Angeles basin (Wilmington, Long Beach, Huntington Beach, Santa Fe Springs, Brea-Olinda, Inglewood, Dominguez, and Coyote West). Of these, two extend offshore, and produce from deep-water turbidite sandstone sequences with net sand thicknesses exceeding 1,000 feet (305 m). All are structural traps, either anticlinal or homoclinal against major faults, and many are situated along regional structural highs such as the Newport-Inglewood trend.

Appraisal of the OCS Potential

Santa Barbara Channel--As a result of exploratory drilling following the OCS sale in 1968, the Santa Barbara Channel is relatively well known. Major unleased areas are in the central and deep parts of the channel and in the waters to the west. The main Pliocene turbidite reservoirs are believed to be restricted to the northeastern edge of the channel in the Dos Cuadras field and to the east. Because these sandstone zones thin rapidly southward and westward, they are considered poor prospective reservoirs in the central and western parts of the channel.

Reservoirs that produce from beneath the Oxnard Plain east of the channel, chiefly sandstone beds in the Sespe Formation, are potential reservoirs south of the seaward extension of the Oak Ridge fault. Other possible reservoirs beneath the channel are sandstone zones in the early Miocene section, fractured shales of the Monterey Formation, and inferred post-late Miocene sandstone zones. Eocene and older sandstone zones probably are present but are not thought to be primary objectives. Well data on recently discovered reservoirs in the offshore Santa Clara and Oak Ridge units are confidential and have not been reviewed in this analysis.

In the unleased central deep part of the channel and westward to the 750-meter (2461 feet) water depth, potential reservoirs are expected to be similar to the late Miocene or older reservoirs in the Santa Ynez Unit. Thick sandstone beds in the Rincon Formation, known only in the South Elwood field (Dames and Moore, 1974), form the main reservoir in that field. The fractured shale there is of lesser importance, yet is a significant prospect because of its widespread occurrence. The nonmarine Sespe Formation grades westward into a shallow-marine facies in which potentially high quality sandstone reservoirs may be present. In the same area, the early Miocene Vaqueros Formation, the main sandstone reservoir in the coastal area west of Santa Barbara, generally is thin, but local thickening may occur. Eocene sandstone zones, although present, probably occur as distal turbidites with low reservoir potential; they have poor productive history onshore.

The main source rocks are believed to be the Miocene shales that are buried deeply enough over most of the basin to have become thermally mature; however, these rocks may not have been sufficiently buried in the most westerly parts of the proposed lease sale area. Structural traps similar to those in leased areas may be present in the unleased areas.

Southern California Borderland (OCS)--OCS Lease Sale 35, held in December, 1975, included much of the available area to and beyond the 200-meter (656 feet) water depth. Appraisals of the petroleum potential of the entire borderland recently have been prepared (Vedder and others, 1974; Taylor, 1976) and supplemented by information from the deep stratigraphic test well, OCS-CAL 75-70 No. 1 (Paul and others, 1976). Much of the nearshore area adjacent to the Los Angeles basin recently has been leased with the exclusion of Santa Monica Bay. Wells near the Santa Monica coast suggest a thinning and shaling-out of the main objective section except in a narrow belt south of the Malibu Coast fault and west of Santa Monica.

In the outer basin area seaward of the Channel Islands, the deep test well at Cortes Bank provided data that seem to enhance the petroleum potential of this part of the borderland. Deep-marine sandstone units of Eocene and early Miocene age have good porosities and are thicker than previously inferred, and are considered good potential reservoir rocks. The distribution of potential reservoir sandstones seaward from Cortes Bank is unknown. Potential source rocks occur in strata of late Eocene and Miocene age. Organic matter in all analyzed Tertiary rocks is immature, but the same rocks might have generated petroleum in adjacent basins if sufficiently buried to have been subjected to high temperatures. Upper Cretaceous strata, known only from three widely scattered seafloor areas of the borderland, are more than 5,000 feet (1524 m) thick in the well at Cortes Bank; but reservoir-quality rocks are present only in the upper part, and the source-rock potential is low. The lower 3,000 feet (914 m) of section in the well, below an unconformity or fault within the Upper Cretaceous strata, contains small amounts of mature organic matter. New information from this well does not warrant a change in previous interpretations of the petroleum potential outside of the Cortes-Tanner Bank area; however, it does indicate the importance of strategically located wells elsewhere in the borderland.

PETROLEUM RESOURCE APPRAISAL

The proposed lease sale area includes parts of three separate provinces of the Pacific Coast Offshore Region. These are the Santa Barbara Channel, the Inner Basins and Banks, and the Outer Basins and Banks of the southern California borderland. An assessment of the sale area indicates that the following amounts of oil and gas resources probably exist that could be recovered under present conditions of economy and technology.

	95% Probability	5% Probability	Statistical Mean
Oil (billions of barrels)	1.9	5.8	3.6
Gas (trillions of cubic feet)	2.2	6.3	3.9

These figures represent that part of the proposed sale area between water depths of 0 to 2,500 meters (0 to 8,200 feet) with the exception of the Inner Basins Province where only the area with water depths greater than 200 meters (656 feet) has been considered in the estimate. In the Inner Basins Province most of the water-covered area above the 200-meter depth is State owned, and much of that outside the 3-mile limit is either excluded from the sale or is already under lease. State acreage, Federal reserves and reservations, and Federal leases granted at previous sales are included in the rest of the general sale area as assessed, but data are not available to make an assessment of these restricted or untested tracts.

The resource estimates represent an aggregate of two of the provinces, Santa Barbara Channel and Outer Basins and Banks, and a restricted part of the Inner Basins Province and are based in part upon volumetric and analog analytical methods. Although appraisals of these provinces were prepared in connection with those reported in U.S. Geological Survey Circular 725, the reader is cautioned that the resource estimates reported in the circular treat offshore areas only out to the 200-meter depth (656 feet).

The following log normal probability curves (fig. 6) show estimates of undiscovered recoverable resources of the California offshore area that are pertinent to proposed OCS Lease Sale 48. The oil curve shows a 95% probability of at least 1.9 billion barrels of oil and a 5% probability of at least 5.8 billion barrels of oil. Other probability estimates can be read directly from these curves.

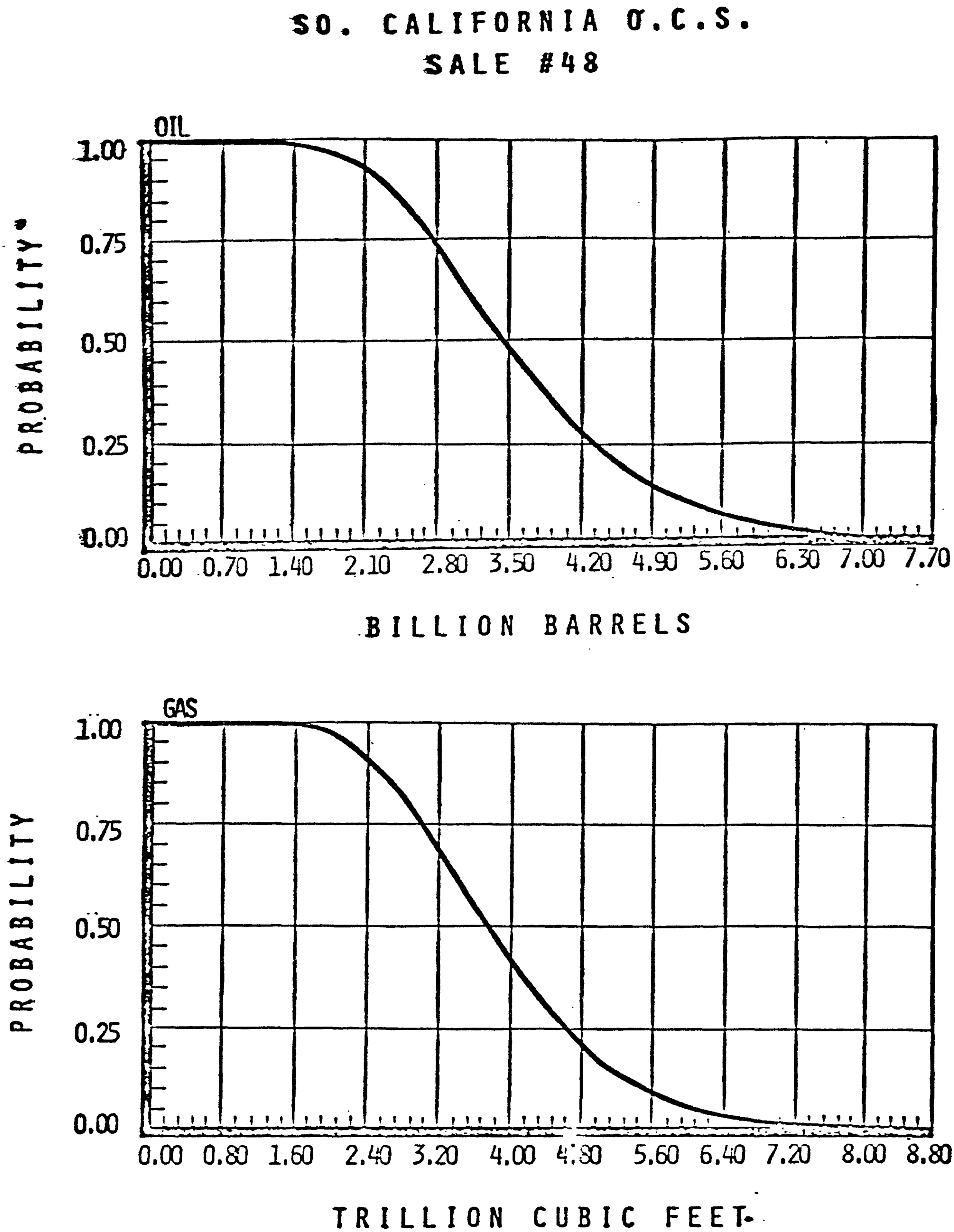

Fig. 6. Lognormal probability curves showing estimates of undiscovered recoverable resources of the area related to proposed OCS Sale 48.

ENVIRONMENTAL HAZARDS

Only a few areas within the southern California borderland have been investigated specifically for the delineation of potential environmental problems that could be detrimental to OCS petroleum exploration and production. Most of the areas that have been studied in detail have been publicly reported (Vedder and others, 1969; Ziony and others, 1974; U.S. Geological Survey, 1975; Campbell and others, 1975; Greene and others, 1975) or are being prepared for publication. In general, the published studies are restricted to the shallow parts of the Santa Barbara Channel, to the Mugu-Santa Monica, San Pedro, and Newport-San Diego shelves, and to parts of the Santa Rosa-Cortes Ridge. The environmental phenomena assessed in these area include faults, seismicity, sediment instability, sediment erosion and hydrocarbon seeps.

Santa Barbara Channel--The major faults in the channel region are the Santa Ynez, Red Mountain, Pitas Point, Oak Ridge--McGrath, "northern and southern Santa Barbara slope", Santa Cruz Island, and Santa Rosa Island faults (fig. 7). Several of these faults or associated faults either are active or potentially active, for they displace Holocene sediment or offset the seafloor (U.S. Geological Survey, 1975, plate 7).

Many submarine slumps and landslides are present on the seafloor slopes of the Santa Barbara Channel. Most of these features are located along the mainland slope and are especially prominent between Point Conception and Goleta Point and in Hueneme Canyon (U.S. Geological Survey, 1975, fig. II-17; Greene, 1976, fig. 4). In addition, buried disturbed strata observed in seismic profiles at the foot of the Channel Islands platform suggest probable landsliding in the past (U.S. Geological Survey, 1975, p. II-145).

page 29 is fig 7

Earthquakes recorded in the Santa Barbara Channel region indicate that the area is seismically active. The epicenters of seismic events greater than Richter magnitude 4.5 that have occurred between 1932 and 1973 are shown in figure 7. Location determinations of earthquakes in the channel prior to 1969 are imprecise because of limited coverage of the network of seismographic stations at the time. Prior to 1969, epicenter locations were probably accurate to within ± 7 miles. After installation of additional seismometers since 1969, location determinations were refined to ± 3 miles. In the Santa Barbara Channel region, four destructive earthquakes have occurred; in 1812, 1925, 1941, and at Point Mugu in 1973 (U.S. Geological Survey, 1975). The maximum credible earthquake predicted for the area is one of Richter magnitude 6 with a recurrence interval of approximately 20 years (U.S. Geological Survey, 1975).

Although the Santa Barbara Channel lies in a seismically active region and the physiography is such that inundation by run-up is possible, especially in the Oxnard Plain area, few tsunamis are documented. Prior to 1967, only three locally generated tsunamis had been recorded in the channel region; these were reported in Santa Barbara in 1812, 1854, and perhaps in 1896 (Iida and others, 1967). No extensive property damage or loss of lives were reported.

Natural hydrocarbon seeps are reported offshore from Coal Oil Point and Point Conception in the Santa Barbara Channel (U.S. Geological Survey, 1975). More than 900 individual seeps have been mapped in a 7 mi. area off Coal Oil Point (Fischer and Stevenson, 1973), and additional seeps occur on the northern shelf of the northern Channel Islands (Wilkinson, 1971).

Quaternary sediments apparently are being actively eroded along the mainland shelf off Carpinteria, Coal Oil Point near Gaviota, and Point Conception (U.S. Geological Survey, 1975). Erosion and transport of Holocene sediments seems to be taking place along the sill that separates the Santa Barbara Basin from the Santa Monica Basin.

Borderland, inner basins and banks--In the Mugu-Santa Monica and San Pedro shelf areas, detailed geophysical investigations have been made, and the geological hazards are reported in the U.S. Geological Survey Open-File Report 75-596 (Greene and others, 1975). Geological environmental studies are underway for the Newport-San Diego shelf and the Santa Barbara Island platform.

Four major fault zones transect the inner basins and banks area; they are the Palos Verdes, Malibu Coast, Newport-Inglewood, and Rose Canyon fault zones (fig. 7). Many faults associated with these zones may be active (Ziony and others, 1974; Jennings, 1975). Most of the active faults in the Mugu-Santa Monica shelf area are short and discontinuous. Of these, the Malibu Coast fault in the northern part of the area probably is the largest and most likely to generate major earthquakes. In the San Pedro shelf area, active faults seem to be the principal geologic hazard. Probably the most important is the offshore extension of the Palos Verdes fault, which is more than 40 miles long and locally offsets the seafloor. Earthquake epicenters along its trace verify its continuing activity. Many other faults that extend upward to the seafloor must be considered environmentally hazardous, as they cut beds of Holocene age (Greene and others, 1975, plate 13).

Areas known to be prone to submarine sliding occur in the submarine canyons and mainland slope of the Hueneme-Mugu shelf, in Santa Monica Canyon, on the slope offshore from Point Fermin, and along the eastern slope of the San Diego Trough (Greene and others, 1975, plates 11, 12). Unconsolidated Quaternary deposits are as much as 600 feet (183 m) thick in the vicinity of Santa Monica Bay, and most of the San Pedro shelf is covered with similar flat-lying sediments.

The inner basin and banks area is moderately active seismically (fig. 7), and seismicity is most prominent in the offshore area between Point Mugu and Point Dume, in the vicinity of the Malibu Coast fault, along the offshore extension of the Palos Verdes fault, and in adjoining areas of the Newport-Inglewood fault zone (Greene and others, 1975, plates 10, 13). Predictions of maximum credible earthquakes and their recurrence intervals have not been made for the inner basins and banks. Only a few locally generated tsunamis have been recorded along the coast between Point Mugu and the Mexican border and none of them caused major damage; one was noted in 1879 at Santa Monica, and two others were reported in 1925 (uncertain) and 1933 at Long Beach (Iida and others, 1967). The 1933 seismic seawave resulted from the March 10, 1933 Long Beach earthquake. Because the area is seismically active, inundation along the coastal lowlands possibly could result from both locally generated and external tsunamis.

Oil and gas seeps have been reported in the northern part of Santa Monica Bay, along the probable extension of the Malibu Coast fault, in southern Santa Monica Bay along the probable extension of the Palos Verdes fault, and offshore between Point Vicente and Point Fermin (Greene and others, 1975, plates 10, 13). Wilkinson (1971) shows two oil seeps and one gas seep in the San Pedro shelf area.

<u>Borderland, outer basins and banks</u>--Few reports have been published on geological environmental problems on the outer part of the borderland. Geological hazards on the northern part of the Santa Rosa-Cortes Ridge and Tanner-Cortes Banks are described in a report by Greene and others (1975), and a detailed analysis of the central part of Santa Rosa-Cortes Ridge and San Nicolas platform is in preparation.

The longest Quaternary fault mapped in the outer basins and banks area is the San Clemente fault; the northwestern segment is 50 miles (80 km) long and the southeastern segment, more than 15 miles (24 km) long (Jennings, 1975). Many other smaller faults cut the area, and some apparently are active (fig. 7). The northern Santa Rosa-Cortes Ridge in particular seems to be tectonically unstable. Faults are numerous, but are most common along the ridge crest where relatively small apparent vertical separations are characteristic (Greene and others, 1975, plate 5). Beneath the flanks of the ridge, faults are less numerous but have greater apparent vertical separations than those on the ridge top. Seafloor offsets above displaced seismic reflectors suggest that some faults are active. In the Tanner-Cortes Banks area, faults are concentrated along the northern flank of Cortes Bank and along the southern edge of the ridges and troughs between the two banks (Greene and others, 1975, plate 2). Many of these faults displace either Holocene sediments or the sea floor.

In the northern Santa Rosa-Cortes Ridge area, many submarine slumps and landslides have occurred along the ridge flanks. Recurrent slumping is likely because slopes are relatively steep, and unconsolidated Holocene sediments are locally thick. Downslope movement by slumping and sediment creep occur along the flanks of Tanner and Cortes Banks. The bank tops, however, are relatively stable and are composed of bedrock with local pockets of unconsolidated Holocene sediments.

Seismicity in the northern Santa Rosa-Cortes Ridge area is moderately active. Most of the earthquake epicenters in this area are randomly scattered, but there is some clustering south of South Point on Santa Rosa Island (Greene and others, 1975, plate 5). Most of the earthquakes in this region have been estimated to be between 2.5 and 4.5 Richter magnitude. During a four-year period between 1970 and 1973, the USGS seismic network recorded 11 earthquakes beneath the ridge ranging from less than 2.5 to greater than 3.5 Richter magnitude (Greene and others, 1975). Several earthquakes have been reported in the vicinity of the San Clemente fault. In 1941, a Richter magnitude 5.9 to 6.0 earthquake was recorded from an area near the southeastern extension of the fault (Lamar and others, 1973). Because Tanner and Cortes Banks lie beyond the limits of the seismographic network, there are no reliable epicenter data and thus no estimates of maximum credible earthquakes and recurrence intervals. Tsunamis have not been reported in the outer basins and banks region of the borderland. However, the shallow water over most ridges and banks in this region could create potential danger to engineered structures in the event that seismic seawaves traveled through the area.

Although no oil and gas seeps have been reported in the northern Santa Rosa-Cortes Ridge and Tanner-Cortes Banks areas, the combined presence of hydrocarbons in the sediments and a large number of faults suggest that surface seeps and subsurface gas-charged sediments may be present. Proprietary data tend to confirm this possibility.

Distribution of sediment types on the northern part of the Santa Rosa-Cortes Ridge (clastic sands on the edges, foraminiferal sands in the center) suggests that bottom currents may be strong on the perimeter and of lesser strength in the center. Both the sparse sediment cover on the ridge top due to the isolation from sediment sources and the abundance of rocky outcrops devoid of sediment suggest the influence of strong current activity (Greene and others, 1975, plates 8, 9). On Tanner and Cortes Banks, strong current activity is suggested by areas of exposed bedrock and by the thinness of the sediment cover over much of the nearby area (Greene and others, 1975, plates 1, 2, 4). The low silt and clay content, relatively good sorting, and coarseness of bank-top sediments also suggest current action, although the coarseness is partly a reflection of the abundant supply of coarse biogenic debris.

Secondary effects, such as seafloor subsidence resulting from fluid withdrawal should be investigated before oil field development, but are beyond the scope of this report.

OPERATIONAL CONSIDERATIONS

Introduction

Information on technological needs, availability of manpower and capital for development of oil and gas, offshore southern California, has been documented in the Final Environmental Statement, OCS Sale No. 35, August 1975, and in the Final Environmental Statement, Oil and Gas Development in the Santa Barbara Channel, March 1976. The same information will apply to OCS Sale No. 48.

Technological Needs

Technology and operational activities for offshore oil and gas exploration and development could involve a variety of specific activities and related facilities. These include geophysical and geological exploration, exploratory and development drilling, separation and treating facilities, crude oil and natural gas pipelines, storage facilities, reservoir stimulation and secondary recovery programs. Installations would vary from platforms fixed to the sea floor to floating facilities.

Operations could be in excess of 100 miles (160 km) from the California mainland. The cost of oil and gas pipeline construction increases as water depth increases. The combination of water depth and distance in some localities could make construction economically unfeasible. A pipeline route having a maximum depth of 2000 feet (610 m) of water could be constructed along the Santa Rosa-Cortes Ridge to the vicinity of Santa Cruz Island, then across the eastern Santa Barbara Channel, a distance in excess of 100 miles (160 km). The selection of transportation systems will be influenced by possible land use restrictions in adjacent coastal areas.

Oil storage facilities could include ocean floor installation or floating storage and treating barges, or tankers may be used in rough waters.

Natural gas in an oil and gas reservoir could be reinjected as a secondary recovery technique to increase the production of oil from the reservoir. The discovery of a large gas reservoir beyond the reach of pipeline transmission may require the construction of a LNG (liquified natural gas) facility.

The distance from shore has other economic impacts. The cost of transporting drilling and production equipment and supplies as well as the transportation of personnel must be considered.

For exploratory drilling, jack-up rig capability is limited to a water depth of 300-350 feet (91-197 meters). Drillships and semi-submersibles can operate at water depths of 1,500 to 2,000 feet (457 to 610 m) or more. Dynamically positioned drillships have the greatest capability of 2,500 to 3,000 feet (762-914 m). By 1980 drilling in water depths of 6,000 feet (1829 m) is forecast.

At present, fixed platforms are capable of being set in 1,000 feet (305 m) depths of underwater completions (UWC) at 1,200-1,500 feet (366-475 m). By 1978-1980 UWC completion depths are projected at 3,000 feet (914 m). A fixed 24-well platform in 400 feet (122 m) of water can presently be ready for production 3 to 4 years after field discovery and delineation. A fixed 40-well platform in 1,000 feet (305 m) of water can be ready for production 6 to 8 years after discovery and delineation.

Drill Rig Availability

Drillships available in California, as of July 1, 1976, are the CUSS I and GLOMAR CORAL SEA.

CUSS I--Drills to 16,000 feet (4,880 m) in 600 feet (183 m) water depth. Socal, California. (Global Marine, Inc. owner).

GLOMAR CORAL SEA--Drills to 25,000 feet (7620 m) in 1,500 feet (457 m) water depth. Exxon, California. (Global Marine, Inc., owner).

The semi-submersible, OCEAN PROSPECTOR, has recently become available.

The April, 1976 issue of Offshore (p. 161-186) itemizes worldwide mobile rig units as:

Under construction	105
Working	291
Idle	39
Enroute	5

It is likely that three to four drilling vessels will be brought in from Japan and other parts of the world within the next several months to explore leases issued in the Sale No. 35 area. The moving in of such drilling vessels requires several months and costs as much as half a million dollars. In order to justify such expenditures, companies must be relatively certain that considerable continuous work will be available.

The incentive to further investment in offshore activity will be influenced by results from Sale No. 35 exploratory drilling, the timeliness in which exploratory plans can be approved, as well as the impact of stipulations and regulations.

The southern California OCS presents a benign physical environment in comparison with Alaska and European North Sea Continental Shelf areas. Relatively steep underwater topography, deep waters, and seismically active areas are some of the features of the southern California OCS which may present siting problems in some instances, but these are not beyond present technological capability. Weather conditions are not as severe as in most other OCS areas, and less so in the protected waters of the Santa Barbara Channel.

Manpower

Sufficient skilled and unskilled manpower to support the proposed OCS Lease Sale 48 exploration, development, and production is available from the adjacent onshore southern California area. Southern California probably has more OCS experienced oil and gas personnel than any other geographic OCS area in the United States, except the Gulf of Mexico.

Some trained manpower would accompany drilling rigs as they moved into another area; other personnel would have to be hired locally or brought in from outside the southern California area. Once activity picked up and became stable, oil field workers from less active areas in the United States would move to the location of new activity. Some personnel within the onshore oil industry would be available as the onshore oil production declines.

Capital Availability

The present and projected demand for oil and gas will encourage the oil industry to explore all domestic resource prospects made available. Sufficient capital can and will be obtained to finance lease exploration, development, and production, provided the necessary incentives for such investment exist.

Time Frame

Estimates of a time frame for exploration, development, and full production of proposed OCS Lease Sale 48 areas after the actual sale are conjectural at best. Speculative factors which can affect timing are drilling rig and equipment availability, water depth, discovery successes, reservoir and hydrocarbon character, economic and political climate, labor disputes and environmental considerations.

It may be noted that shallow-water, potential reservoirs would be tested first as a simple matter of sound economic planning. Considering the most attractive shallow-water tracts and experiences gained from Santa Barbara Channel and Lease Sale 35 OCS ventures, it is estimated that exploratory drilling would commence 0 to 2 years after lease sale with initial production occurring 3 to 5 years after the sale. Maximum production of such "optimum" tracts would occur 5 to 8 years post sale.

It is again emphasized that the above estimates are conjectural and apply only for the shallower, most attractive lease tracts. Deeper more unknown areas would be explored, developed, and leased on a later schedule as the overall situation dictated.

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