# SANTA BARBARA-VENTURA BASIN PROVINCE

by James M. Galloway

## LOCATION

The Santa Barbara-Ventura Basin province is located offshore southern California (fig. 69). This Federal offshore assessment province is within the western portion of the Transverse Ranges geomorphic province (which is so named because its east-west orientation runs counter to the predominant north-northwest grain of the region's major structural trends) and the western portion of the Santa Barbara-Ventura basin proper.

The depositional basin is bounded to the north by the Santa Ynez and related faults; to the east by the San Gabriel fault; to the south by a series of thrusts and lateral faults related to the Malibu Coast-Santa Monica fault zone, the Santa Cruz Island fault, and the Santa Rosa fault; and to the west by a poorly defined basement trend ("Amberjack high" of Crain and others (1985)). The basin extends in an east-west direction approximately 160 miles and in a north-south direction approximately 40 miles. The offshore portion of the basin is referred to commonly and herein as the Santa Barbara Channel.

The Santa Barbara-Ventura Basin province comprises only the submerged portion of the basin that lies seaward of the Federal-State boundary. As such, the assessment province is bounded to the north, east, and south by the 3-mile line. It is approximately 90 miles long and 20 miles wide and encompasses an area of about 1,800 square miles. Water depth in the assessment province ranges from 100 to 1,800 feet.

## GEOLOGIC SETTING

The oldest known sedimentary rocks in the basin date from the Early Cretaceous(?) (fig. 70). These basinal sedimentary formations are deposited on a probable metamorphic or metasedimentary basement complex. Mesozoic- and Paleogene-aged rocks in the modern Santa Barbara-Ventura basin were originally deposited in a forearc setting. This sequence of Cretaceous to lower Oligocene, predominantly marine sedimentary rocks, is well known from outcrops and boreholes. The composite section is remarkably complete; however, erosion (resulting in local unconformities) and structural complications have

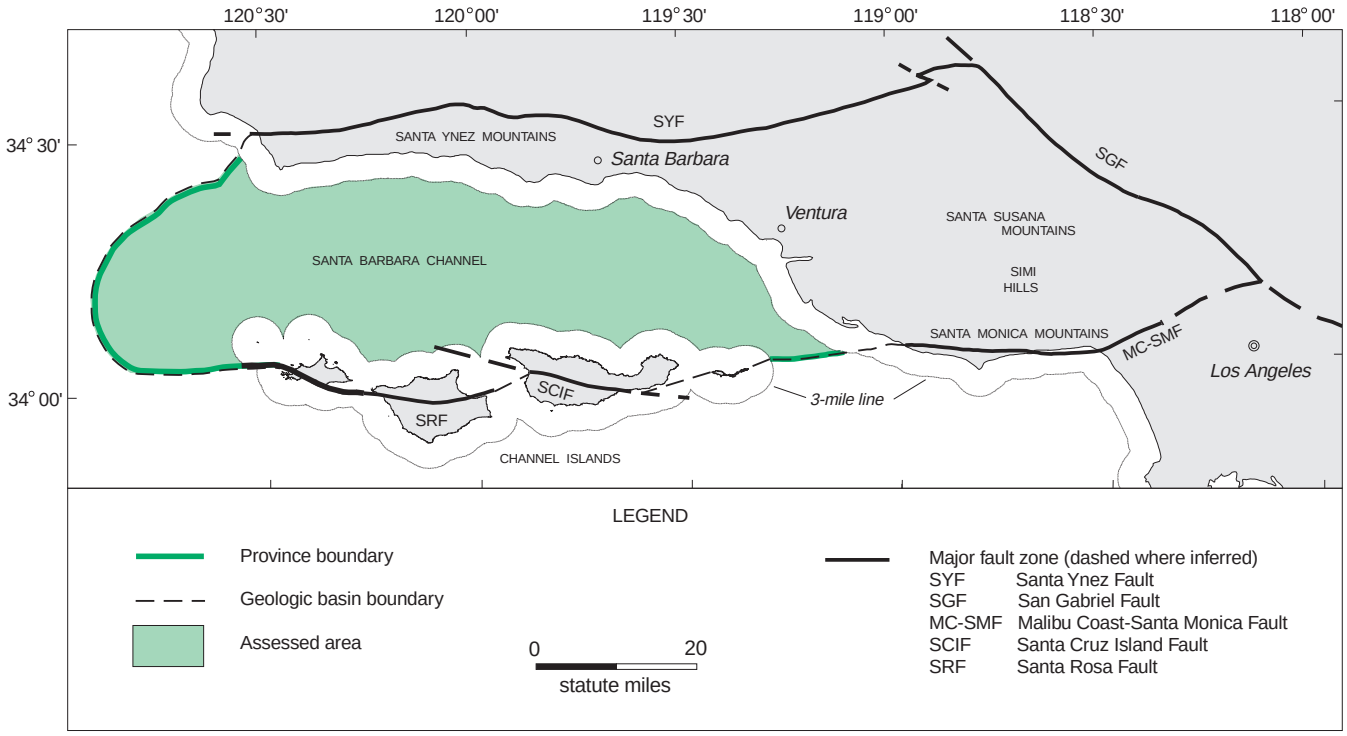


**Figure 69.** *Map of the Santa Barbara-Ventura Basin province showing assessed area.*

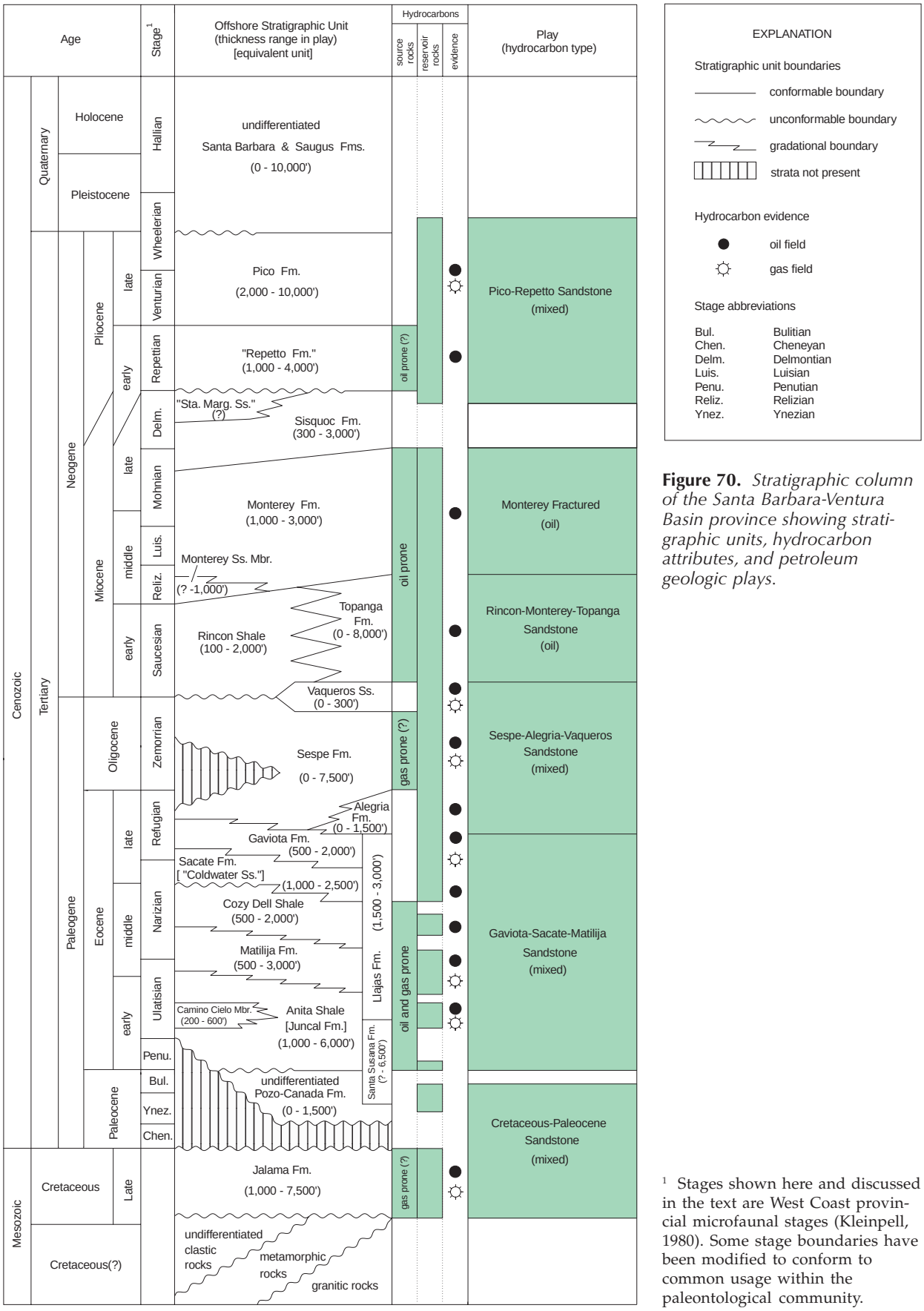


**Figure 70.** *Stratigraphic column of the Santa Barbara-Ventura Basin province showing stratigraphic units, hydrocarbon attributes, and petroleum geologic plays.*

[1] Stages shown here and discussed in the text are West Coast provincial microfaunal stages (Kleinpell, 1980). Some stage boundaries have been modified to conform to common usage within the paleontological community.

removed significant rock volumes in many areas. Major regional unconformities exist in the mid-Upper Cretaceous, Paleocene, and Oligocene sections.

The Cretaceous-Paleogene forearc basin bordered the paleosubduction zone in an elongate, north-south direction. The forearc basin predominantly filled from highland sediment sources to the east. In the Santa Barbara Channel and Outer Borderland areas (see Victor, this report), isochoral maps suggest thinning to paleosouth (present-day west). Bathyal paleobathymetric microfossil indicators are common. During the Eocene, however, changes to shallower water depths due to basin filling, lateral facies changes, and continued sediment influx from the continental highlands produced important stratigraphic variations (Ingle, 1981).

Shallow marine and nonmarine Oligocene sedimentary rocks mark the end of the forearc basin and the beginning of a fundamental reorganization of the regional structure. Paleomagnetic data suggest that the Santa Barbara-Ventura basin has rotated clockwise up to 120 degrees since the Eocene (Kamerling and Luyendyk, 1979). Significant episodes of rotation continued, possibly as late as the late Miocene or early Pliocene (Hornafius and others, 1986). Structural analyses (Yeats and others, 1994) and Global Positioning System telemetry suggest that rotation and basin compression continue today.

Rotation accompanied late Oligocene(?) to early Miocene regional extension and a rapid subsidence of the basin. In the Santa Barbara Channel, upper bathyal to middle bathyal foraminifera are common throughout the Miocene and show a quick transition from nonmarine to bathyal marine (>600 feet water depth) depositional environments. Shoaling by the late Miocene to early Pliocene is apparent (Ingle, 1981).

Late Pliocene and Quaternary tectonics within the basin, expressed as large-scale thrust faults and rapid deformation of young sediments, suggest significant crustal shortening. Most of the mapped structural trends reflect the latest regional diastrophism (fig. 71).

## STRATIGRAPHY

The stratigraphic terminology within the basin is complicated (fig. 70). This stems from complex structural geology, common facies changes within formations, the time-transgressive nature of many stratigraphic units, and widely scattered exposures that led to multiple names for rock units with lithostratigraphic similarities. Additionally, provincial terms were imported from other basins and applied to Ventura basin strata.

Basement rocks beneath much of the basin were likely deposited in a subduction complex. These rocks are typically Jurassic(?) to Cretaceous metasediments and metavolcanics and are referred to as the Franciscan Complex. They are exposed in the upturned basin flanks and penetrated by the relatively few exploratory wells that reached basement. Mesozoic plutonic rocks whose tectonic origin is uncertain have been observed on Santa Cruz Island (Gordon and Weigand, 1994).

A thick (>40,000 feet) composite sedimentary section, ranging in age from Cretaceous to Holocene, exists within the basin. Most of the section is of marine origin. One significant nonmarine section and several volcanic units are also present.

Cretaceous-aged rocks are prominently exposed in the Santa Ynez Mountains, Santa Monica Mountains, Simi Hills, and on the Channel Islands. These rocks have also been penetrated in boreholes, particularly along some of the major anticlinal trends (fig. 71). Most Cretaceous strata observed in the Santa Barbara Channel are referred to for this assessment as Jalama Formation. These rocks lie directly on basement or are separated from older Cretaceous rocks by a regional unconformity. The total Cretaceous section may exceed 6,500 feet in thickness.

Paleocene-aged rocks are not well represented in the basin. On the Channel Islands, rocks assigned to the Pozo and Canada Formations may be analogous to similarly aged rocks (Ynezian to Bulitian Stages) in offshore boreholes. In many places within the basin, the Paleocene is absent. The Channel Islands section may be as much as 1,500 feet thick. Offshore, the section partially penetrated by boreholes measures at least 1,000 feet thick.

Eocene-aged rocks are well represented in outcrop and in the subsurface. In the west and central portions of the Santa Barbara Channel, Eocene strata are found unconformably overlying basement, Cretaceous, or Paleocene rocks. The formations penetrated offshore include the lithologic and temporal equivalents to the Anita Shale (Juncal Formation), Matilija Formation, Cozy Dell Shale, Sacate Formation ("Coldwater Sandstone"), and Gaviota Formation. Although minor nonmarine and volcanic units have been noted, the Eocene section here generally represents a marine forearc environment with a gradual shallowing-upward tendency. Significant sand-rich sections, some of which are quite massive, are intercalated with prominent shaley units.

In the eastern portion of the Santa Barbara Channel, the Anita Shale grades into the Juncal Formation (which contains the sandy Camino Cielo Member). Farther east, the lithological distinctions between the members and formations fade, and the name "Llajas Formation" has been applied to the Eocene

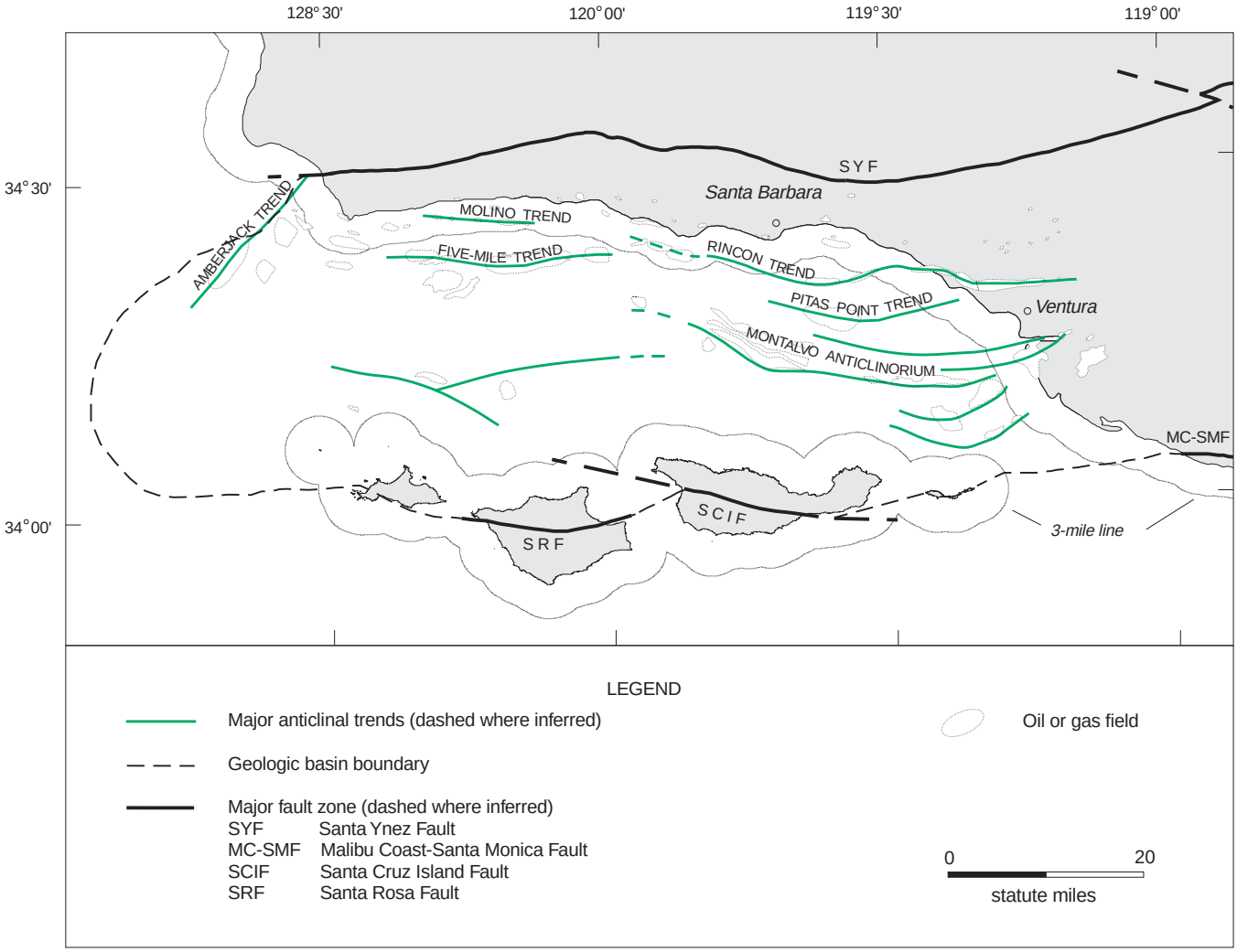


**Figure 71.** *Map of the Santa Barbara-Ventura basin showing anticlinal trends and select fields.*

section. The Eocene section, as interpreted on common-depth-point seismic-reflection profiles, may exceed 15,000 feet in thickness.

The Oligocene section is represented by the primarily nonmarine to shallow marine Sespe Formation and the shallow marine Alegria Formation. Analysis of the Sespe Formation suggests that it records numerous depositional environments; these include braided streams, meandering rivers, and fan deltas. The Sespe Formation is unique and easily recognized in outcrop and in well cuttings due to its variegated sandstones, conglomerates, and claystones. The Alegria Formation consists primarily of sandstone and siltstone. In some parts of the basin, the Sespe-Alegria (undifferentiated) strata conformably or paraconformably overlie the Eocene section. Elsewhere, this contact is a distinct angular unconformity.

Likewise, the upper contact of the Sespe with the overlying Neogene unit varies from gradational and conformable to a strong angular unconformity. The entire Oligocene section may exceed 7,500 feet in thickness within parts of the basin. In the Santa Barbara Channel, the section averages 3,000 to 4,000 feet thick. The nonmarine Oligocene section apparently thins toward the west and is entirely replaced by marine sedimentary rocks in the Point Conception area. (Detailed descriptions of the Paleogene sequence stratigraphy may be found in Campion and others (1994).)

The Miocene-aged section in the Santa Barbara Channel is composed of the Vaqueros Sandstone, Rincon Shale, Monterey Formation, and Sisquoc Formation ("Santa Margarita Sandstone", locally). This sequence marks a sudden subsidence of the basin in the late Oligocene (late Zemorrian) (Campion and others, 1994) or early Miocene (early Saucesian) (Stanley and others, 1992), followed by almost 20 million years of deposition in

basin-plain, slope, banktop, and shelf environments. With the exception of the Vaqueros Sandstone, which is a coarse- to fine-grained, shallow-water sandstone, and the relatively restricted, Relizian(?)-aged Hueneme Sandstone, the other units are primarily composed of fined-grained and bioclastic claystones, siliceous shales, porcelanites, diatomites, and siltstones (see Garrison and Douglas (1981) and Isaacs and Garrison (1983) for more detail). Locally important volcanic units are intercalated with the Rincon and Monterey Formations. The maximum thickness of the Miocene section may exceed 8,000 feet.

The Pliocene-aged section is represented by the "Repetto"[10] and Pico Formations. The Repetto Formation unconformably or paraconformably overlies the Sisquoc Formation. As is implied by the name, the Repetto Formation is coincident with the Repettian Stage. Conformably above the Repetto Formation is the Pico Formation. Both formations indicate bathyal to neritic, turbidite and fan environments. The Repetto consists of thin, rhythmically interbedded, medium- to fine-grained, generally nonchannelized sandstones and shales; whereas, the Pico commonly consists of arkosic sandstones and gravels, often found within channels and other lenticular bodies.

Pliocene paleobathymetric indicators suggest a generally shallowing-upward sequence in the Santa Barbara Channel. Much of the Pliocene section has been stripped away on the crest of the prominent anticlinal trends within the Channel area (fig. 71). However, in the basin's Pliocene depocenter, near the City of Ventura, the Pliocene section is in excess of 14,000 feet thick.

## STRATIGRAPHIC OCCURRENCE OF PETROLEUM

Oil and natural gas reservoirs have been identified in nearly every formation (Cretaceous through Pleistocene) in the Santa Barbara-Ventura basin (fig. 70). As ranked by volume of oil and condensate produced (onshore and offshore) to date, the most important reservoir formations include (1) Pliocene Pico and Repetto turbidite sandstones; (2) Oligocene-Miocene Sespe and Vaqueros nonmarine to shallow-marine, coarse clastics; (3) middle Miocene Modelo sandstones; and (4) middle Miocene Monterey fractured biogenic siliceous shales.

Minor oil production has also been obtained from lower Miocene sandstones of the Topanga Formation, Rincon Formation, and Hueneme Sandstone and from Eocene sandstones of the Gaviota Formation, Sacate Formation, Cozy Dell Shale, and Matilija Formation. Insignificant production has been obtained from Cretaceous reservoirs in the basin.

Important dry gas accumulations have been identified in the Pliocene and Oligocene-Miocene reservoirs. Wet gas (with condensate) accumulations have been found predominantly in the Eocene reservoirs.

With the exception of the Modelo reservoirs (which are found in the eastern onshore portion of the basin and are not considered a play in the Santa Barbara Channel) and the small Cretaceous reservoirs, the established reservoir groups in the offshore part of the basin have provided the basis for the definition of plays and assessment of the undiscovered resource potential.

## EXPLORATION HISTORY

Petroleum seeping to the Earth's surface has been exploited in this basin since prehistoric times. Distilleries and refineries were built in the 1850's and 1860's to process and refine seepage oil and tar. As early as 1861, "oil tunnels" (adits) were driven into the flanks of Sulphur Mountain, near Santa Paula, to tap the reservoir strata that fed the seeps. Indeed, the oldest fields were developed under rules adopted by "petroleum mining districts." Some of the earliest-discovered fields are still in production today. A few individual wells and oil tunnels have produced for over 100 years.

Since 1861, at least 155 oil and gas fields have been discovered in the greater Santa Barbara-Ventura basin. Of these, 33 were discovered before 1901. However, of these 33 shallow fields, only 4 (Bardsdale, Silverthread, Tar Creek-Topatopa, and Torrey Canyon) may ultimately produce over 10 MMbbl of oil; all 4 fields were augmented by later-discovered deep production.

The Summerland field, discovered in 1890, played an important role in the petroleum development history of the basin. It was there in 1894 that the first offshore oil wells in North America were drilled. Oil wells were drilled from piers through caissons driven into the seafloor. The subsequent development and haphazard abandonment of the field not only modified the exploration paradigm (to include offshore potential) but also began to shape the aesthetic and environmental mores that continue to cause conflict to this day.

It was not until the post-World War II advent of modern offshore exploration technology that the Federal offshore area was explored in earnest. Extensive bottom sampling, coring, and seismic programs have been conducted in the area since

[10] The U.S. Geological Survey has abandoned the term "Repetto" (originally used to describe rocks that were deposited during the Repettian Stage) (Keroher and others, 1966); however, the term is widely used by the geological community and is used in this report.

then. The first Federal lease in the Santa Barbara Channel (on the western end of the Carpinteria field) was not issued until 1966, more than 100 years after petroleum development began in the basin.

Advances in exploration and development technology over the past 135 years have continued to further the search for petroleum into heretofore unreachable locations. As a result of this search, at least 12 fields that will ultimately produce in excess of 100 MMbbl of combined oil-equivalent resources (MMBOE) have been discovered; this estimate includes the supergiant (>1,000 MMBOE) Ventura-San Miguelito-Rincon field.

Considerable unleased, undrilled, and unexplored acreage exists in the Santa Barbara Channel. Furthermore, prospective to highly prospective areas throughout the basin have been precluded from exploration by the creation of parks, wilderness areas, and marine sanctuaries. These areas nevertheless contribute to the undiscovered petroleum potential of the basin.

## PLAYS

Based on reservoir rock stratigraphy and the exploration and production history of the Santa Barbara-Ventura basin, six petroleum geologic plays were defined for analysis (fig. 70). With the exception of the Cretaceous-Paleocene Sandstone play, which has only three known accumulations in the basin, all of the plays were assessed to estimate their volume of undiscovered conventionally recoverable resources. These five assessed plays consist of (1) Pico-Repetto Sandstone play (Pliocene turbidite sandstones), (2) Monterey Fractured play (Miocene fractured siliceous shales), (3) Rincon-Monterey-Topanga Sandstone play (lower Miocene channel and fan sandstones), (4) Sespe-Alegria-Vaqueros Sandstone play (Oligocene shallow- to nonmarine coarse clastics), and (5) Gaviota-Sacate-Matilija Sandstone play (Eocene channel and fan sandstones).

These plays, described in the following parts of this section, are broadly related to plays in the State offshore and onshore portions of the basin, which have been described and assessed by the U.S. Geological Survey (Keller, 1995).

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Original recoverable reserves were estimated for all known accumulations in the entire (onshore and offshore) basin[11]. Field reserves estimates were subdivided on a play basis. Public and private sources of information were used to develop the data base. If existing sources of data were insufficient, production and reserves were estimated. Reserves estimates of partially or wholly undeveloped fields are highly speculative.

Play-specific estimates of undiscovered conventionally recoverable resources have been developed using the discovery assessment method. For each assessed play, a pool-size distribution of the entire play area (including discovered and undiscovered pools, onshore and offshore) was developed. Estimates of undiscovered conventionally recoverable resources in the Federal offshore portion of each play were subsequently calculated using a subjective area proportionality factor. These play-specific estimates have been statistically aggregated to estimate the total volume of undiscovered conventionally recoverable resources in the Federal offshore portion of the basin (i.e., the Santa Barbara-Ventura Basin province). Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the total volume of undiscovered conventionally recoverable resources in the Santa Barbara-Ventura Basin province is estimated to be 1.85 Bbbl of oil (including oil and condensate) and 4.62 Tcf of gas (including associated and nonassociated gas) (mean estimates). This volume may exist in 174 fields with sizes ranging from approximately 70 Mbbl to 215 MMbbl of combined oil-equivalent resources (fig. 72). A large proportion of these resources (approximately 46 percent on a combined oil-equivalence basis) is estimated to exist in the Monterey Fractured play. The low, mean, and high estimates of resources in the province are listed in table 23 and illustrated in figure 73.

### Undiscovered Economically Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the province that may be economically recoverable under various economic scenarios have been developed using the economic assessment method. Select data used to develop the resource estimates are shown in appendix D.

As a result of this assessment, 1.17 Bbbl of oil (including oil and condensate) and 2.91 Tcf of gas (including associated and nonassociated gas) are estimated to be economically recoverable from the Santa Barbara-Ventura Basin province under economic conditions existing as of this assessment (i.e., the $18-per-barrel economic scenario) (table 24). Larger volumes of resources are expected to be

[11] The author is solely responsible for the accuracy of the production and reserves data used in this analysis.

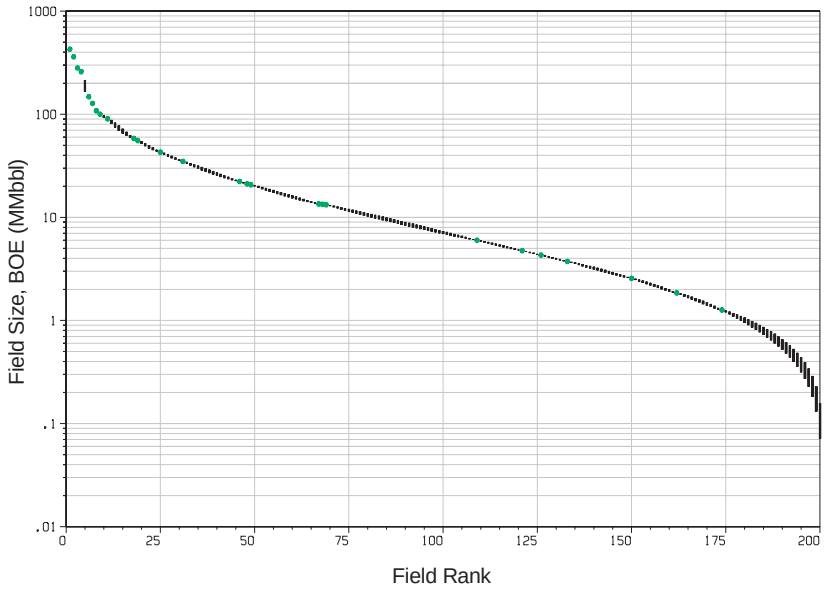


**Figure 72.** *Field-size rank plot of estimated conventionally recoverable resources of the Santa Barbara-Ventura basin province. Sizes of discovered fields are shown by dots. Sizes of undiscovered fields are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile value of a probability distribution, respectively.*

**Table 23.** *Estimates of undiscovered conventionally recoverable oil and gas resources in the Santa Barbara-Ventura Basin province as of January 1, 1995, by play. All estimates are risked values. The low, mean, and high estimates correspond to the 95th-percentile, mean, and 5th-percentile values of a probability distribution, respectively. Percentile values are not additive; some total mean values may not equal the sum of the component values due to independent rounding.*

| Play | Oil (MMbbl) | | | Gas (Bcf) | | | BOE (MMbbl) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Mean | High | Low | Mean | High | Low | Mean | High |
| Pico-Repetto Sandstone | 216 | 299 | 400 | 617 | 1,244 | 2,168 | 323 | 521 | 782 |
| Monterey Fractured | 959 | 1,004 | 1,050 | 1,129 | 1,201 | 1,277 | 1,162 | 1,218 | 1,276 |
| Rincon-Monterey-Topanga Sandstone | 140 | 144 | 149 | 249 | 259 | 269 | 185 | 191 | 196 |
| Sespe-Alegria-Vaqueros Sandstone | 263 | 277 | 291 | 1,227 | 1,338 | 1,454 | 489 | 515 | 542 |
| Gaviota-Sacate-Matilija Sandstone | 117 | 122 | 127 | 541 | 572 | 605 | 215 | 224 | 233 |
| Cretaceous-Paleocene Sandstone | not assessed | | | | | | | | |
| *Total Province* | *1,744* | *1,847* | *1,953* | *3,840* | *4,615* | *5,481* | *2,432* | *2,668* | *2,918* |

**Figure 73.** *Cumulative probability plot of estimated undiscovered conventionally recoverable resources of the Santa Barbara-Ventura Basin province.*

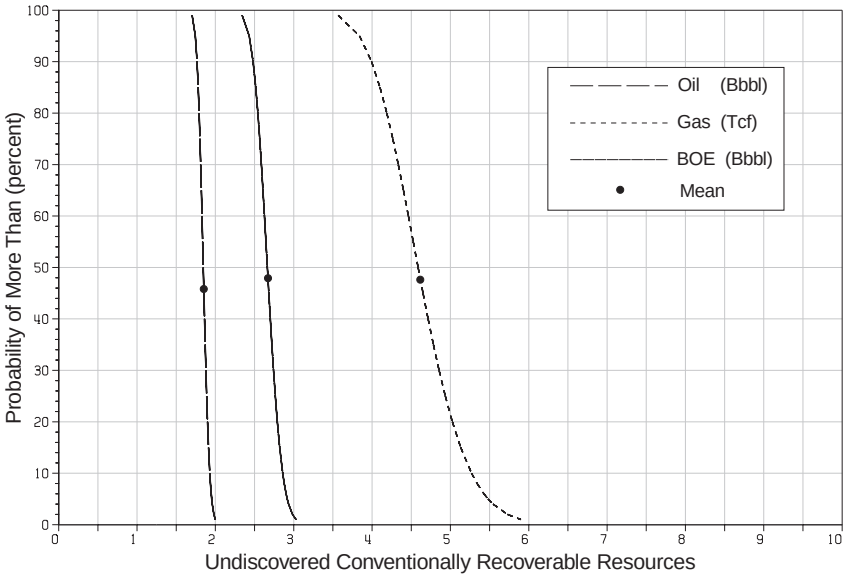

**Table 24.** *Estimates of undiscovered economically recoverable oil and gas resources in the Santa Barbara-Ventura Basin province as of January 1, 1995, by economic scenario. All estimates are risked mean values. The $18-per-barrel scenario is based on prices of $18 per bbl of oil and $2.11 per Mcf of gas; the $25-per-barrel scenario is based on prices of $25 per bbl of oil and $2.94 per Mcf of gas; the $50-per-barrel scenario is based on prices of $50 per barrel of oil and $5.87 per Mcf of gas.*

| Economic Scenario | Oil (MMbbl) | Gas (Bcf) | BOE (MMbbl) |
|---|---|---|---|
| $18 per barrel | 1,166 | 2,913 | 1,684 |
| $25 per barrel | 1,370 | 3,425 | 1,980 |
| $50 per barrel | 1,644 | 4,108 | 2,375 |

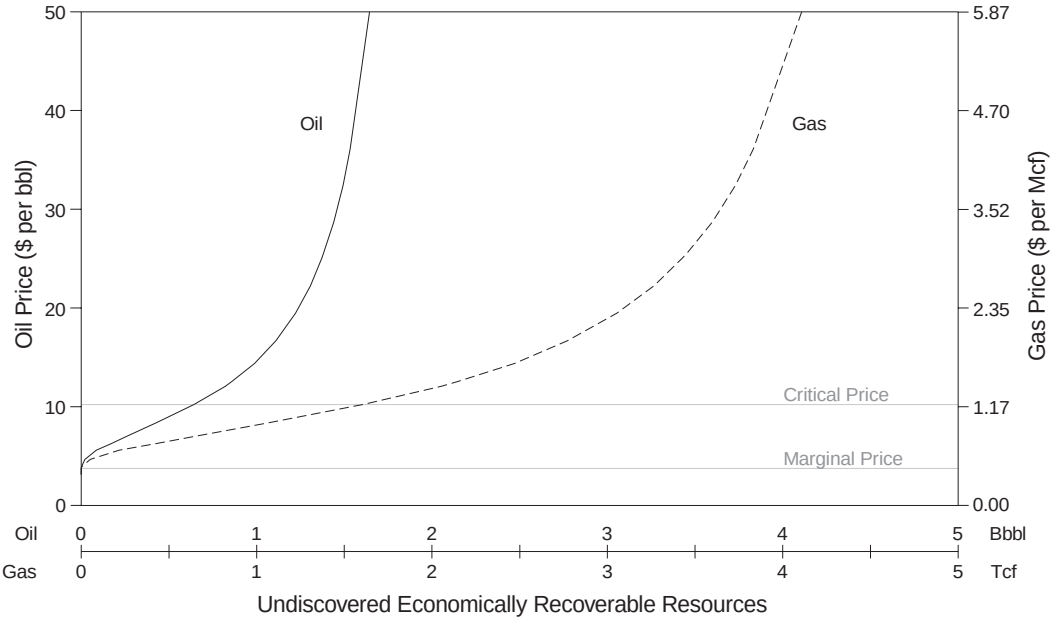


**Figure 74.** *Price-supply plot of estimated undiscovered economically recoverable resources of the Santa Barbara-Ventura Basin province.*

economically recoverable under increasingly favorable economic conditions (fig. 74).

## Total Resource Endowment

As of this assessment, original recoverable reserves in 26 fields in the province were estimated to be 1.14 Bbbl of oil and 2.39 Tcf of gas. These discovered resources and the aforementioned undiscovered conventionally recoverable resources collectively compose the province's estimated total resource endowment of 2.99 Bbbl of oil and 7.01 Tcf of gas (table 25).

**Table 25.** *Estimates of the total endowment of oil and gas resources in the Santa Barbara-Ventura Basin province. Estimates of discovered resources (including cumulative production and remaining reserves) and undiscovered resources are as of January 1, 1995. Estimates of undiscovered conventionally recoverable resources are risked mean values. Some total values may not equal the sum of the component values due to independent rounding.*

| Resource Category | Oil (Bbbl) | Gas (Tcf) | BOE (Bbbl) |
|---|---|---|---|
| Cumulative Production | 0.49 | 0.67 | 0.61 |
| Remaining Reserves | 0.65 | 1.72 | 0.96 |
| Undiscovered Conventionally Recoverable Resources | 1.85 | 4.61 | 2.67 |
| *Total Resource Endowment* | *2.99* | *7.01* | *4.24* |

## ACKNOWLEDGMENTS

During the course of the 4 years this project has been underway, a great many professionals provided critical input and peer review. The author has been able to draw upon many years, and sometimes decades, of experience regarding the Santa Barbara-Ventura basin, which the following individuals have provided: J.P. Chauvel and Greg Cavette (UNOCAL), James Crouch (J.K. Crouch and Associates, Inc.), Dennis Giovannetti (Vastar Resources), Ron Heck and Ed Edwards (Heck & Associates), Tom Hopps (Rancho Energy Consultants), Marc Kamerling and Chris Sorlien (University of California Santa Barbara, Institute of Crustal Studies), Margaret Keller (U.S. Geological Survey), Pat Kinnear and Steve Fields (California Division of Oil, Gas, and Geothermal Resources). Cathie Dunkel, Michael Brickey, Ken Piper, Scott Drewry, and Margaret Keller provided their valuable editing skills. To these people, and to many others who have provided helpful suggestions and criticism, the author offers his profound thanks.

## ADDITIONAL REFERENCES

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Conservation Committee of California Oil and Gas Producers, 1991
Conservation Committee of California Oil and Gas Producers, 1993
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# PICO-REPETTO SANDSTONE PLAY

## PLAY DEFINITION

The Pico-Repetto Sandstone play of the Santa Barbara-Ventura Basin province includes known and prospective oil and gas accumulations in Pliocene- and early Pleistocene-aged reservoirs. This is an established play; original recoverable reserves in onshore and offshore fields exceed 1.94 Bbbl of oil and condensate and 3.28 Tcf of associated and nonassociated gas.

Pliocene strata are distributed throughout the basin; however, this play is limited to the central and eastern portions of the basin (fig. 75) where the reservoir sandstones are known to be abundant and where the depositional thickness of the play exceeds 2,000 feet. The Federal offshore portion of the play is limited to the eastern part of the Santa Barbara Channel; it encompasses an area of about 400 square miles.

## PETROLEUM GEOLOGIC CHARACTERISTICS

Reservoir rocks of this play are primarily sandstones of the Repetto and Pico Formations (fig. 70). Thin-bedded, glauconitic, turbidite sandstones deposited in a bathyal environment are typical of the Repetto Formation. Arkosic sandstones, gravels, and sandy siltstones deposited in an upper bathyal to inner neritic environment are characteristic of the Pico Formation. Sandstones often compose over 50 percent of the rock volume in parts of the play area. The Repetto Formation exceeds a thickness of 4,000 feet. The Pico Formation has a maximum thickness of over 10,000 feet in the basin's Pliocene depocenter.

The source rocks for the oil and gas reservoired in the Pico and Repetto Formations are probably the Miocene Monterey Formation (fig. 70). It is possible that deeply buried, lower Pliocene claystones and mudstones are an additional petroleum source; although, geochemical data suggest that much of the Pliocene section is thermally immature (Yeats and Taylor, 1990).

Traps within this play will be predominantly anticlines, faulted anticlines, and fault blocks. Less-common traps include unconformities on the flanks of folds and permeability barriers. Important structural trends have been identified in the play area, but some trapping mechanisms have not been adequately tested offshore. In particular, primary stratigraphic traps and subthrust accumulations are statistically underrepresented in the known fields.

## DISCOVERIES

The largest productive accumulations in the play (based on original recoverable reserves) include the Ventura-San Miguelito-Rincon field (discovered 1919; 1,770 MMBOE), Dos Cuadras field (1968; 281 MMBOE), Carpinteria field (1966; 129 MMBOE), and the Saticoy-South Mountain (Bridge Pool) field (1955; 86 MMBOE). The first production from this play was obtained from oil tunnels at the Santa Paula field as early as 1861. For the purpose of resource assessment, it was assumed that the largest accumulation in the play has been discovered.

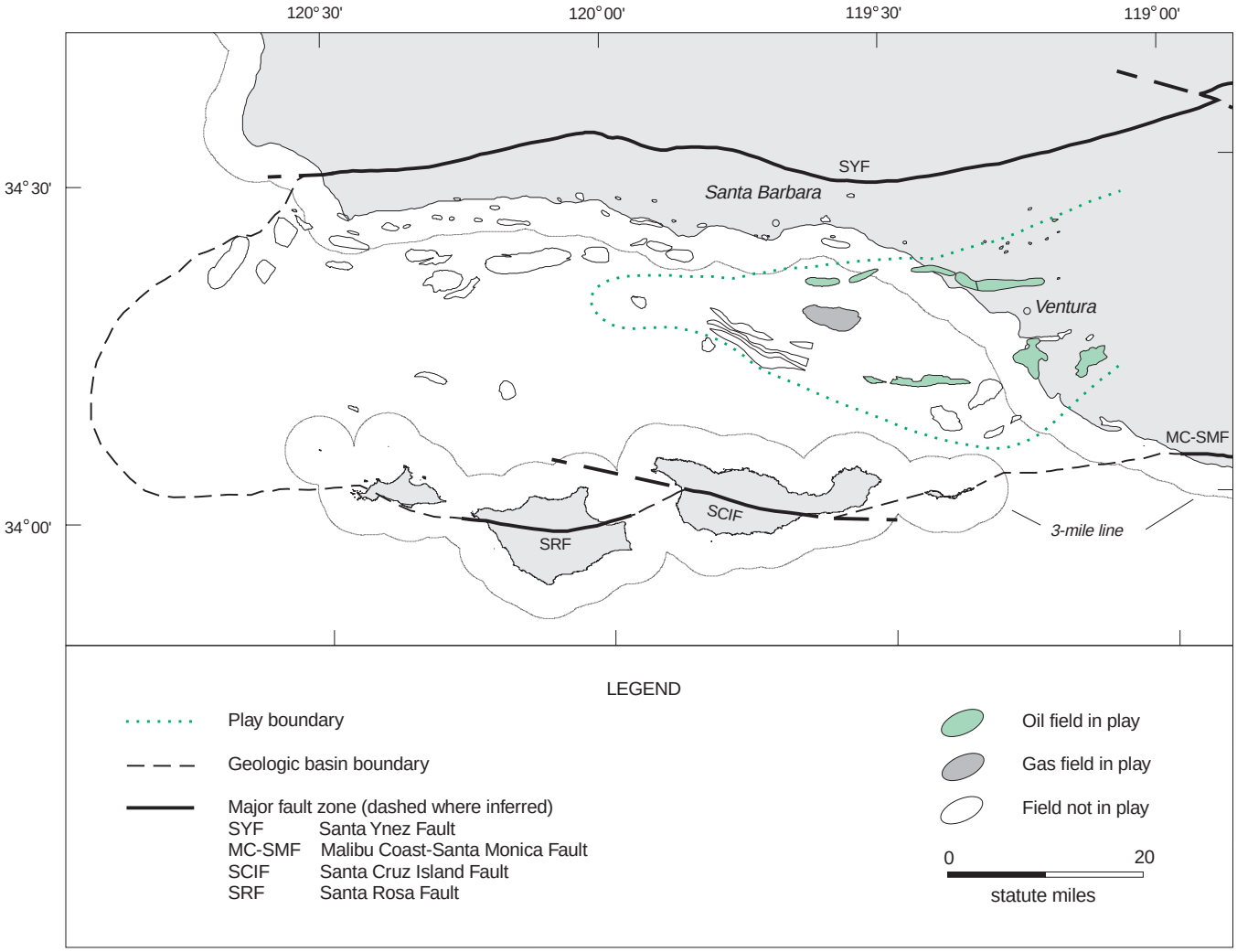


**Figure 75.** *Map of the Pico-Repetto Sandstone play, Santa Barbara-Ventura basin showing select fields.*

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the entire play have been developed using the discovery assessment method with pool-size data from 26 onshore and offshore discovered accumulations in the play. Estimates of undiscovered resources in the Federal offshore portion of the play were subsequently calculated using a subjective area-proportionality factor. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the entire play is estimated to contain 748 MMbbl of oil (including oil and condensate) and 3.11 Tcf of gas (including associated and nonassociated gas) (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in 54 pools with sizes ranging from approximately 4 Mbbl to 795 MMbbl of combined oil-equivalent resources (fig. 76). Of these, 3 pools may exceed 100 MMBOE and an additional 11 pools may exceed 10 MMBOE. Analysis of the discovered pools (each with original recoverable reserves in excess of 10 MBOE) suggests that the undiscovered pools will contain primarily oil and associated gas and that some nonassociated gas pools are probable.

The Federal offshore portion of the play is estimated to contain approximately 40 percent of these undiscovered conventionally recoverable resources, which is 299 MMbbl of oil (including oil and condensate) and 1.24 Tcf of gas (including associated and nonassociated gas) (mean estimates). The low, mean, and high estimates of resources in the Federal offshore portion of the play are listed in table 23.

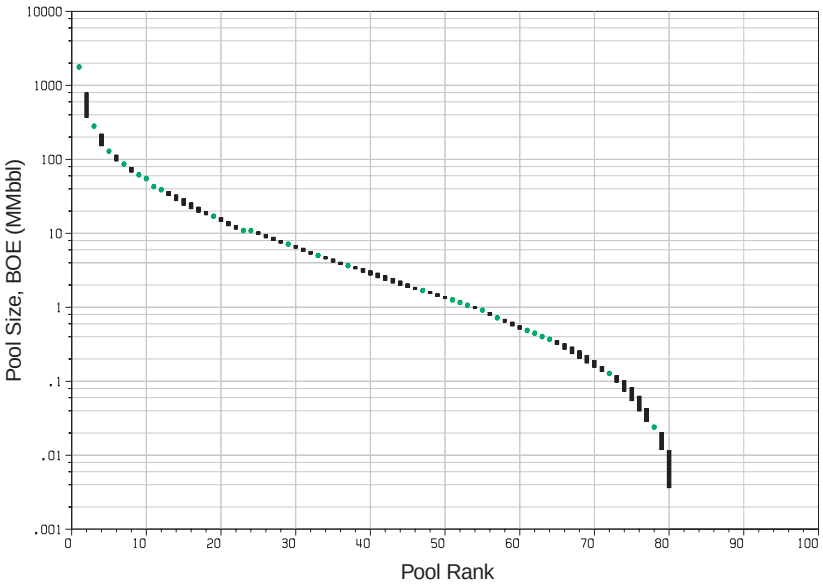


**Figure 76.** *Pool-size rank plot of estimated conventionally recoverable resources of the Pico-Repetto Sandstone play, Santa Barbara-Ventura basin. Sizes of discovered pools are shown by dots. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

# MONTEREY FRACTURED PLAY

## PLAY DEFINITION

The Monterey Fractured play of the Santa Barbara-Ventura Basin province includes known and prospective oil accumulations in middle to late Miocene-aged reservoirs of the Monterey Formation. These reservoirs characteristically have secondary fracture porosity. This is an established play; original recoverable reserves in onshore and offshore fields exceed 1.09 Bbbl of oil and 1.74 Tcf of associated gas.

The Monterey Formation is distributed throughout the Santa Barbara-Ventura basin (fig. 77). In the eastern part of the basin east of the Ojai field, sandy Monterey strata are known as the Modelo Formation. (The Modelo Formation has not been assessed herein because these facies are primarily found in the onshore part of the basin.) The Monterey Formation is exposed on the north flank of the basin in seacliffs and on the seafloor. On the south flank of the basin, the Monterey Formation and coeval volcaniclastics are exposed on the Channel Islands and on the seafloor. The Federal offshore portion of the play encompasses an area of about 1,500 square miles.

## PETROLEUM GEOLOGIC CHARACTERISTICS

Reservoir rocks of this play are fractured zones within the Monterey Formation (fig. 70). Silica diagenesis (which causes the rock mass to become increasingly brittle) coupled with late Neogene compressional tectonics have formed these reservoirs. If either component is missing, a highly prospective fractured reservoir will not form.

The Monterey Formation is a self-sourcing rock unit (fig. 70). In the Santa Barbara-Ventura basin, the Monterey is known to be highly petroliferous and is estimated to have expelled 10 to 20 Bbbl of oil. Much of the Monterey Formation is now within the main zone of oil generation ("oil window"). The generation of Monterey-sourced crude oils is much debated. Empirical evidence suggests that the Monterey Formation is capable of producing oils with a wide range of physical properties and characteristics (e.g., gravity, sulphur content, and viscosity).

Traps within this play are predominantly complexly faulted anticlines. Less-common traps will include normal- and thrust-faulted blocks. Primary stratigraphic traps and stratigraphic components of combination traps are not well recognized or understood in the Monterey Formation, but they may provide important trapping mechanisms for future discoveries within the basin.

## DISCOVERIES

The largest productive accumulations in Monterey fractured rocks of this play (based on original recoverable reserves) include the Hondo field (discovered 1969; 393 MMBOE), Pescado field (1970; 127 MMBOE), and South Ellwood Offshore field (1969; 62 MMBOE). Other large, undeveloped accumulations have been identified offshore. The earliest recognized production from "fractured shales" of the Monterey Formation in the Santa Barbara-Ventura basin was obtained in 1917 at the North Sulphur Mountain area

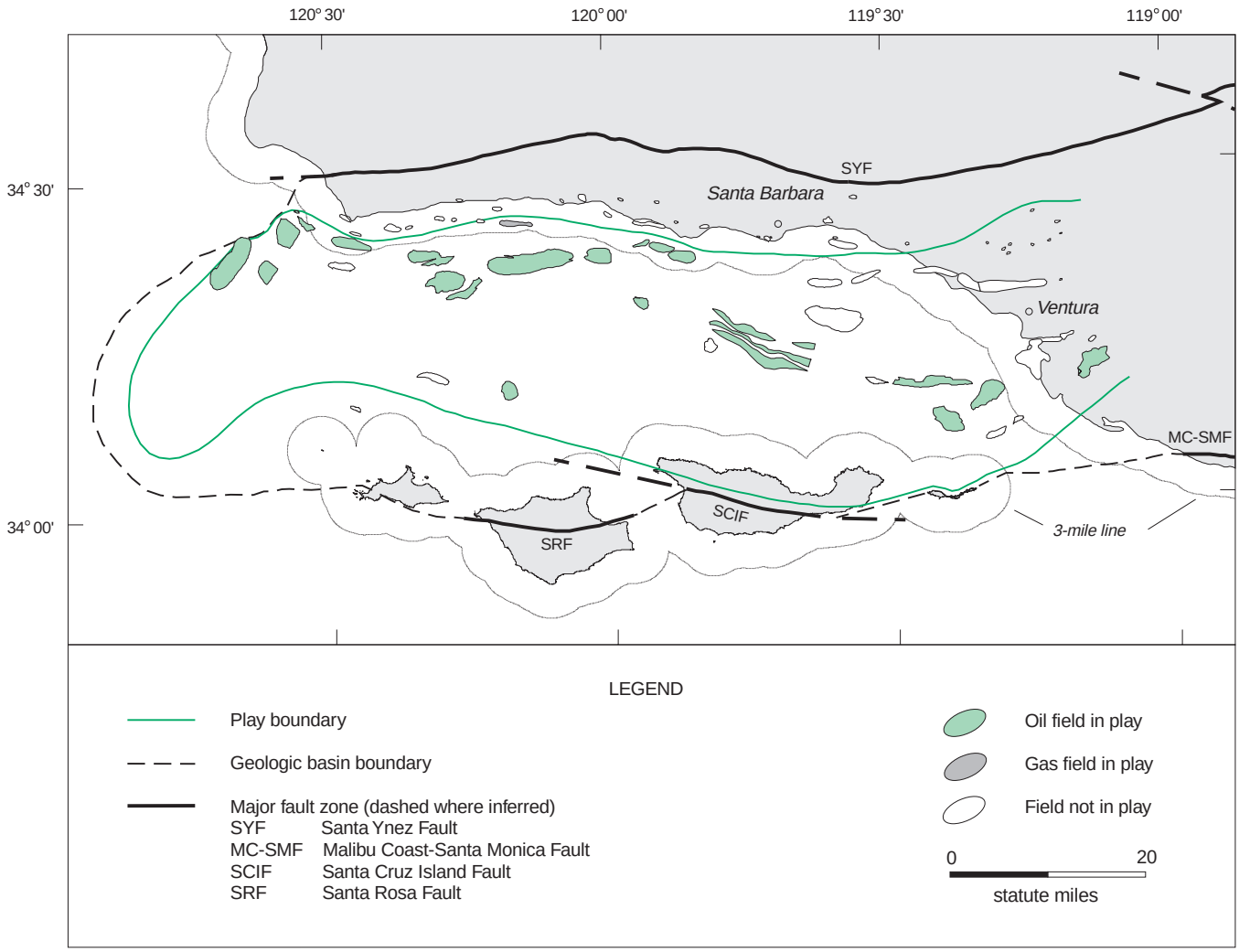


**Figure 77.** *Map of the Monterey Fractured play, Santa Barbara-Ventura basin showing select fields.*

of the Ojai field. For the purpose of resource assessment, it was assumed that the largest accumulation in the play has been discovered.

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the entire play have been developed using the discovery assessment method with pool-size data from 26 onshore and offshore discovered accumulations in the play. Estimates of undiscovered resources in the Federal offshore portion of the play were subsequently calculated using a subjective area-proportionality factor. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the entire play is estimated to contain 1.34 Bbbl of oil (including oil and condensate) and 1.60 Tcf of gas (including associated and nonassociated gas) (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in 104 pools with sizes ranging from approximately 205 Mbbl to 225 MMbbl of combined oil-equivalent resources (fig. 78). Of these, 3 pools may exceed 100 MMBOE and an additional 35 pools may exceed 10 MMBOE. Analysis of the discovered pools suggests that the undiscovered pools will contain primarily oil and associated gas.

The Federal offshore portion of the play is estimated to contain approximately 75 percent of these undiscovered conventionally recoverable resources, which is 1.00 Bbbl of oil (including oil and condensate) and 1.20 Tcf of gas (including associated and nonassociated gas) (mean estimates). The low, mean, and high estimates of resources in the Federal offshore portion of the play are listed in table 23.

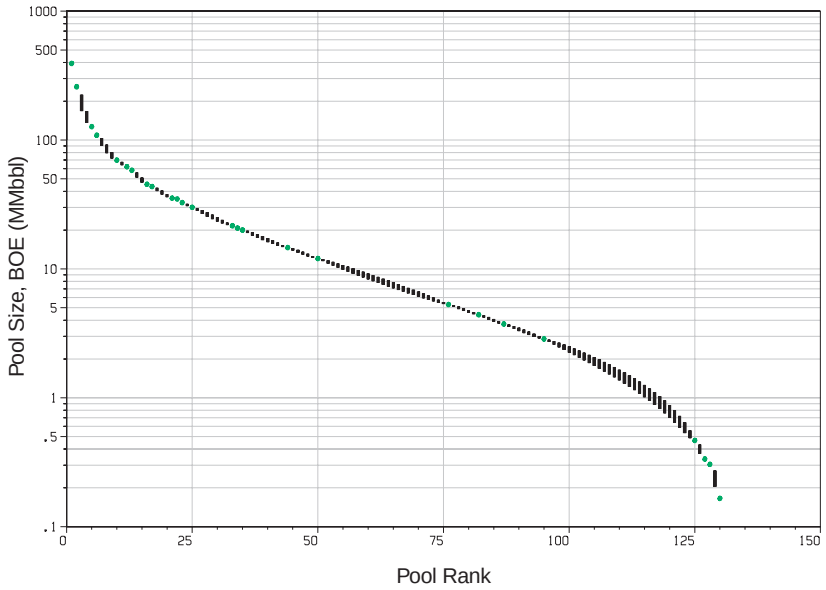


**Figure 78.** *Pool-size rank plot of estimated conventionally recoverable resources of the Monterey Fractured play, Santa Barbara-Ventura basin. Sizes of discovered pools are shown by dots. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

## RINCON-MONTEREY-TOPANGA SANDSTONE PLAY

### PLAY DEFINITION

The Rincon-Monterey-Topanga Sandstone play of the Santa Barbara-Ventura Basin province includes known and prospective oil and associated gas accumulations in early Miocene- to middle Miocene-aged reservoirs. This is an established play; original recoverable reserves in onshore and offshore fields exceed 156 MMbbl of oil and 188 Bcf of associated gas.

This play is limited to two noncontiguous areas in the basin (fig. 79). Lower Miocene (Saucesian) Rincon sandstones and middle Miocene (Relizian to Luisian) lower Monterey sandstones are present in the north-central part of the Santa Barbara Channel. Strata assigned to the lower to middle Miocene Topanga Formation, the lower to middle Miocene San Onofre Breccia, and the lower Miocene (Saucesian to Relizian) Hueneme Sandstone are exposed in outcrop and in boreholes in the southeastern Santa Barbara Channel, along the Oakridge trend, in the Santa Monica Mountains, and on the Channel Islands. The Federal offshore portion of the play encompasses an area of about 160 square miles.

### PETROLEUM GEOLOGIC CHARACTERISTICS

Reservoir rocks of this play, as identified in oil fields, are primarily sandstones deposited in deep-water fans and channels. The sandstone reservoirs in the northern subarea of the play have good porosity (20 to 30 percent) and good permeability (400 to 600 millidarcies). Stacked sand bodies are as thick as 150 feet, and the sandy zones may have a gross thickness in excess of 1,000 feet. The sandstone reservoirs in the southeastern subarea of the play vary in porosity and permeability. The Topanga sandstones have good porosity (20 to 30 percent) and fair to very good permeability (200 to 1,000 millidarcies). The Hueneme Sandstone has very good porosity (30 to 35 percent) and good to excellent permeability (500 to 1,500 millidarcies).

Multiple source rocks are likely for this play. Reservoirs containing medium- to low-gravity, sulphurous, asphaltic oil are probably sourced from the Monterey Formation. Locally, particularly in the northern subarea, fine-grained clay shales of the Rincon Formation may also be a significant source of petroleum (Stanley and others, 1992). The deposition of lower to middle Miocene volcanics in the area of this play may have altered the thermal maturation history of potential source strata.

Traps within this play are predominantly structural but contain important stratigraphic components. The majority of the discovered fields in this play are in faulted anticlines. In some of the fields, particularly in the northern subarea, lenticular, sinuous channel sandstones complicate the reservoir geometry. The basal transgressive Hueneme Sandstone commonly occupies depressions incised into the underlying Sespe Formation, and as such, pinchouts may be an important trapping mechanism in future discoveries.

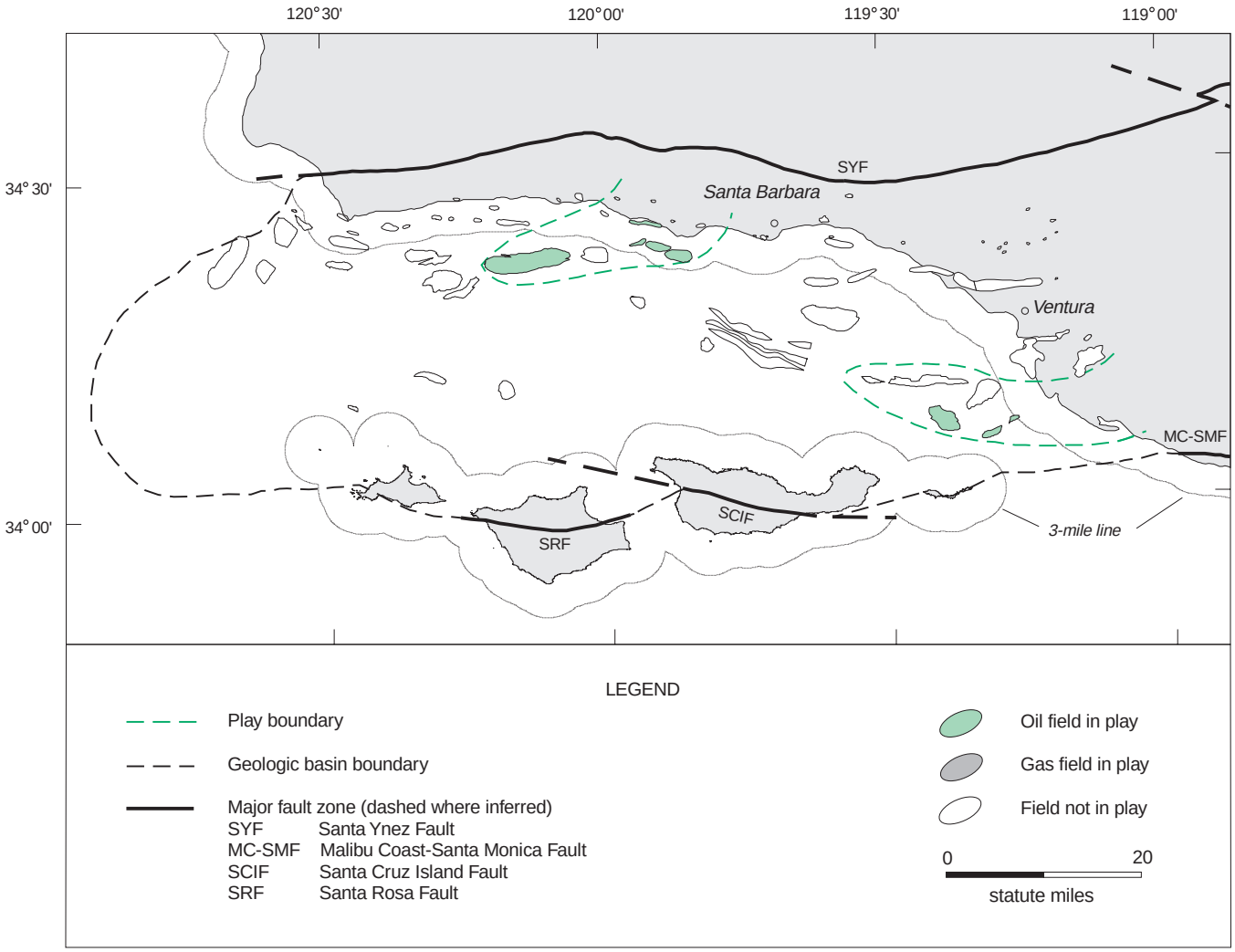


**Figure 79.** *Map of the Rincon-Monterey-Topanga Sandstone play, Santa Barbara-Ventura basin showing select fields.*

## DISCOVERIES

The largest productive accumulations in the play (based on original recoverable reserves) include the Oakridge field (Lower Monterey/Topanga/Vaqueros zone; discovered 1952; 24 MMBOE), Hueneme field (Hueneme/Sespe zones; 1969; 17 MMBOE), Sockeye field ("Upper Topanga" zone; 1970; 14 MMBOE), and South Ellwood Offshore field (Rincon zone; 1965; 7 MMBOE). Additional undeveloped discoveries in this play have been made at the Coal Oil Point Offshore field, "Embarcadero Offshore" field, and Hondo field (Lower Monterey Sands zone). Significant additional, undeveloped reserves are estimated for South Ellwood Offshore field. The earliest known oil production from reservoirs in this play occurred in 1931 at the Ellwood field. It is unclear from the old records whether the production was obtained from fractured shales or sandstone stringers within the Rincon Formation.

For the purpose of resource assessment, it was assumed that the largest accumulation in the play has been discovered. However, giant accumulations in nearby analogous basins (e.g., Kettleman North Dome field (Temblor zone; 725 MMBOE) in the San Joaquin basin and San Ardo field (540 MMBOE) in the Salinas basin) in strata equivalent to this play suggest that this assumption may be conservative.

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the entire play have been developed using the discovery assessment method with pool-size data from eight onshore and offshore discovered accumulations in the play. Estimates of undiscovered resources in the Federal offshore portion of the play were subsequently calculated using a subjective

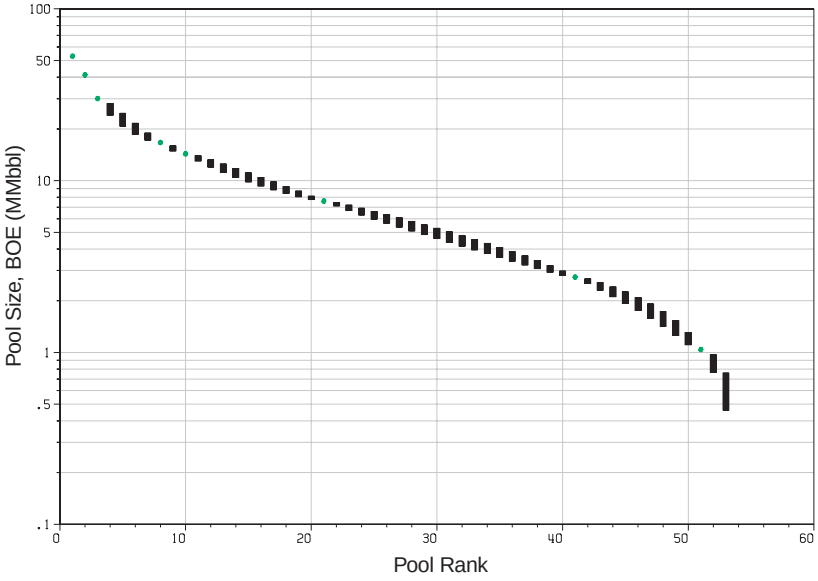


**Figure 80.** *Pool-size rank plot of estimated conventionally recoverable resources of the Rincon-Monterey-Topanga Sandstone play, Santa Barbara-Ventura basin. Sizes of discovered pools are shown by dots. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

area-proportionality factor. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the entire play is estimated to contain 241 MMbbl of oil (including oil and condensate) and 432 Bcf of gas (including associated and nonassociated gas) (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in 45 pools with sizes ranging from approximately 460 Mbbl to 30 MMbbl of combined oil-equivalent resources (fig. 80). Analysis of the discovered pools suggests that the undiscovered pools will contain primarily medium- to low-gravity oil and associated gas.

The Federal offshore portion of the play is estimated to contain approximately 60 percent of these undiscovered conventionally recoverable resources, which is 144 MMbbl of oil (including oil and condensate) and 259 Bcf of gas (including associated and nonassociated gas) (mean estimates). The low, mean, and high estimates of resources in the Federal offshore portion of the play are listed in table 23.

## SESPE-ALEGRIA-VAQUEROS SANDSTONE PLAY

### PLAY DEFINITION

The Sespe-Alegria-Vaqueros Sandstone play of the Santa Barbara-Ventura Basin province includes known and prospective accumulations of oil and associated gas and of non-associated gas in late Eocene- and Oligocene- to early Miocene-aged reservoirs. This is an established play; original recoverable reserves in onshore and offshore fields exceed 580 MMbbl of oil and condensate, and over 1.58 Tcf of associated and nonassociated gas.

Formations in this play are exposed in the Santa Ynez Mountains on the north flank of the basin, on the Channel Islands on the south flank of the basin, and in prominent structural trends (such as the Montalvo Anticlinorium) within the basin (fig. 71). The formations are also penetrated by numerous boreholes offshore. On the basis of these exposures and interpretation of seismic-reflection profiles, it is presumed that these strata are present throughout the offshore portion of the basin (fig. 81). The shallow-marine Alegria Formation is coeval with and replaces the nonmarine to shallow-marine Sespe Formation in the western portion of the basin. The distribution of the Vaqueros Sandstone is less certain. The Federal offshore portion of the play encompasses an area of about 1,700 square miles.

### PETROLEUM GEOLOGIC CHARACTERISTICS

Reservoir rocks of this play are primarily coarse clastics. Nonmarine "red beds" within the Sespe Formation are interpreted to represent braided and meandering fluvial systems. Conglomerate, sandstone, siltstone, and mudstone are the predominant lithologies. Sandy and silty facies suggestive of a fan-delta deposit, dating from the late Eocene, may mark the oldest Sespe. Shallow-marine sandstones of the lower Oligocene Alegria Formation are coeval with parts of the Sespe and have been referred to as "marine Sespe." Much of the middle Zemorrian Stage is absent from the section above lower

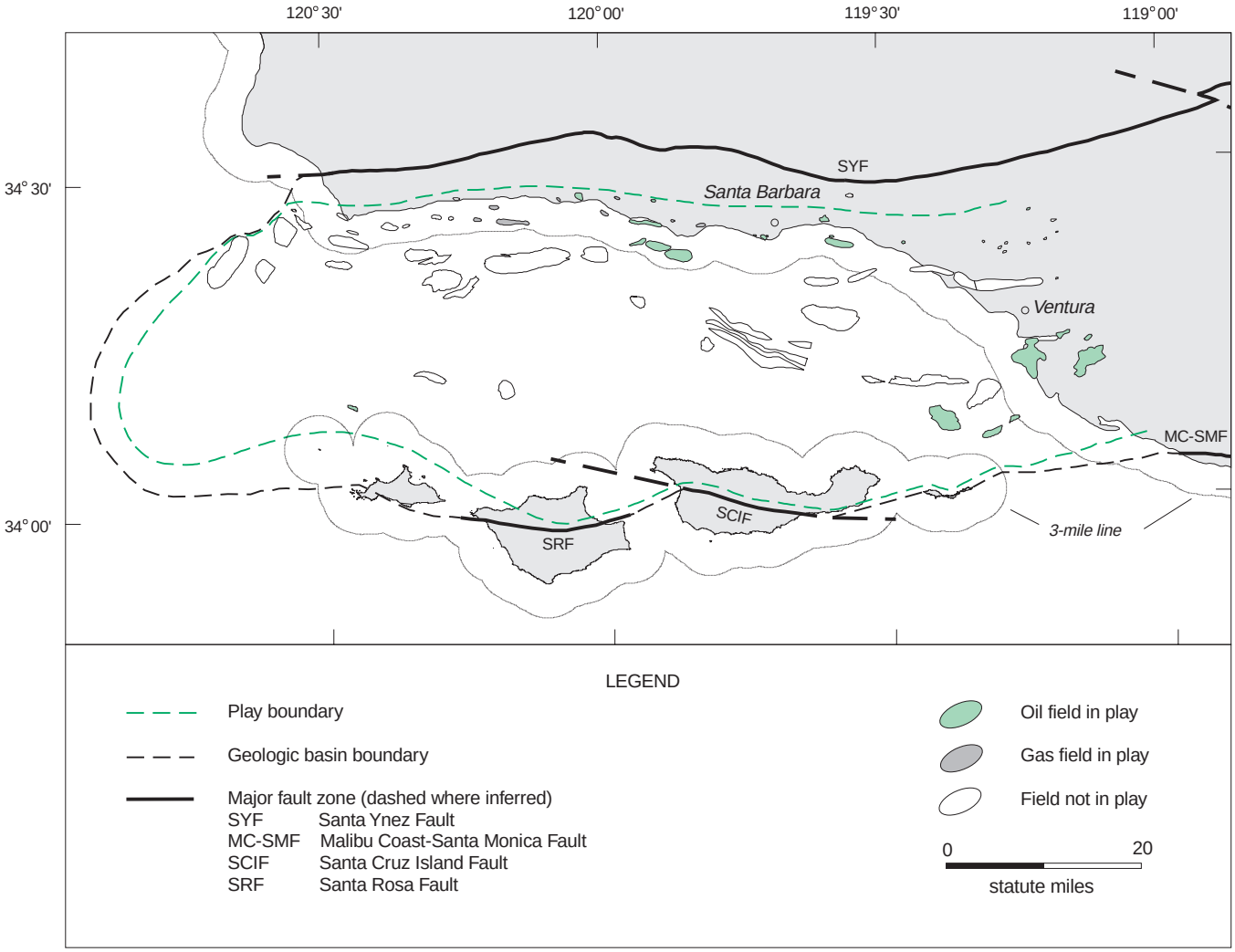


**Figure 81.** *Map of the Sespe-Alegria-Vaqueros Sandstone play, Santa Barbara-Ventura basin showing select fields*

Sespe/Alegria strata (Howard, 1988; Campion and others, 1994).

The upper portion of the Sespe Formation, like the lower portion, is easily recognizable in outcrop and well cuttings by its variegated nature. It too is dominated by sand-rich fluvial facies. The shallow-marine Vaqueros Sandstone, where present, represents a nearshore to shelf deposit, which locally may also represent submarine canyon fill. The entire Sespe-Alegria-Vaqueros section may be more than 7,500 feet thick in parts of the basin, but averages 3,000 to 4,000 feet thick in the Santa Barbara Channel.

The formations in this play are not generally considered to be prospective source rocks for oil. Likely oil sources include Eocene deep-water shales and overlying Miocene formations. The anomalous number of nonassociated gas fields in the play (relative to the other plays in the basin) may suggest that a local dry-gas source rock exists within the play. If so, the gas could be sourced from land-derived woody or coaly debris in the shallow-marine or continental-marine transitional section.

Important trapping mechanisms within this play include both structural and stratigraphic components. Based on analysis of existing fields within the play, anticlines, faulted anticlines, and fault blocks may provide the most common traps. Stratigraphic traps and combination (stratigraphic-structural) traps are also present.

## DISCOVERIES

The largest productive accumulations in the play include the South Mountain field, (Sespe zones; discovered 1916; 153 MMBOE), Ellwood field (Vaqueros zone; 1928; 125 MMBOE), Tar Creek-Topatopa area of the Sespe field (Vaqueros and Sespe zones; 1887; 56 MMBOE), and Molino Offshore gas field

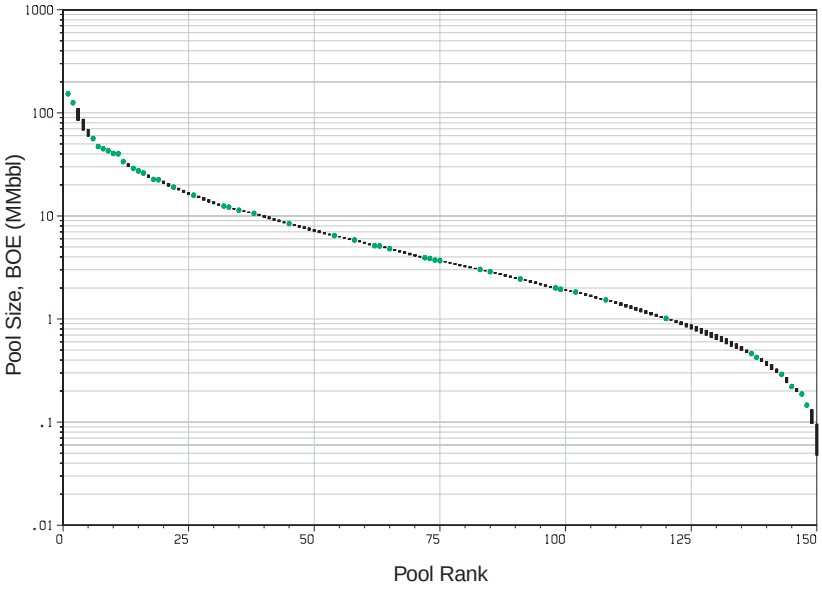


**Figure 82.** *Pool-size rank plot of estimated conventionally recoverable resources of the Sespe-Alegria-Vaqueros Sandstone play, Santa Barbara-Ventura basin. Sizes of discovered pools are shown by dots. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

(Vaqueros and Sespe zones; 1962; 47 MMBOE). The earliest production in the play was obtained from the fields in Sespe Canyon in 1887. For the purpose of resource assessment, it was assumed that the largest accumulation in the play has been discovered.

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the entire play have been developed using the discovery assessment method with pool-size data from 44 onshore and offshore discovered accumulations in the play. Estimates of undiscovered resources in the Federal offshore portion of the play were subsequently calculated using a subjective area-proportionality factor. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the entire play is estimated to contain 413 MMbbl of oil (including oil and condensate) and 2.00 Tcf of gas (including associated and nonassociated gas) (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in 106 pools with sizes ranging from approximately 45 Mbbl to 110 MMbbl of combined oil-equivalent resources (fig. 82). Of these, 20 pools may exceed 10 MMBOE. Analysis of the discovered pools suggests that undiscovered pools will contain primarily oil and that some nonassociated gas pools are probable.

The Federal offshore portion of the play is estimated to contain approximately 67 percent of these undiscovered conventionally recoverable resources, which is 277 MMbbl of oil (including oil and condensate) and 1.34 Tcf of gas (including associated and nonassociated gas) (mean estimates). The low, mean, and high estimates of resources in the Federal offshore portion of the play are listed in table 23.

# GAVIOTA-SACATE-MATILIJA SANDSTONE PLAY

## PLAY DEFINITION

The Gaviota-Sacate-Matilija Sandstone play of the Santa Barbara-Ventura Basin province includes known and prospective accumulations of oil and associated gas and of nonassociated gas in Eocene- to early Oligocene(?)-aged reservoirs. This is an established play; original recoverable reserves in onshore and offshore fields exceed 130 MMbbl of oil and condensate and 840 Bcf of associated and nonassociated gas.

Eocene and lower Oligocene strata are known from exposures in the Santa Ynez Mountains on the north flank of the basin and from similar exposures on the Channel Islands. Many exploratory and production wells have also penetrated these rocks offshore. From these exposures and interpretation of seismic-reflection profiles, Eocene and lower Oligocene formations are assumed to be distributed throughout the basin (fig. 83). It is suspected that the reservoirs degrade in quality with increasing depth of burial; therefore, these rocks are not considered prospective beneath the basin's Pliocene depocenter in the eastern part of the Santa Barbara Channel and adjacent onshore area. The Federal

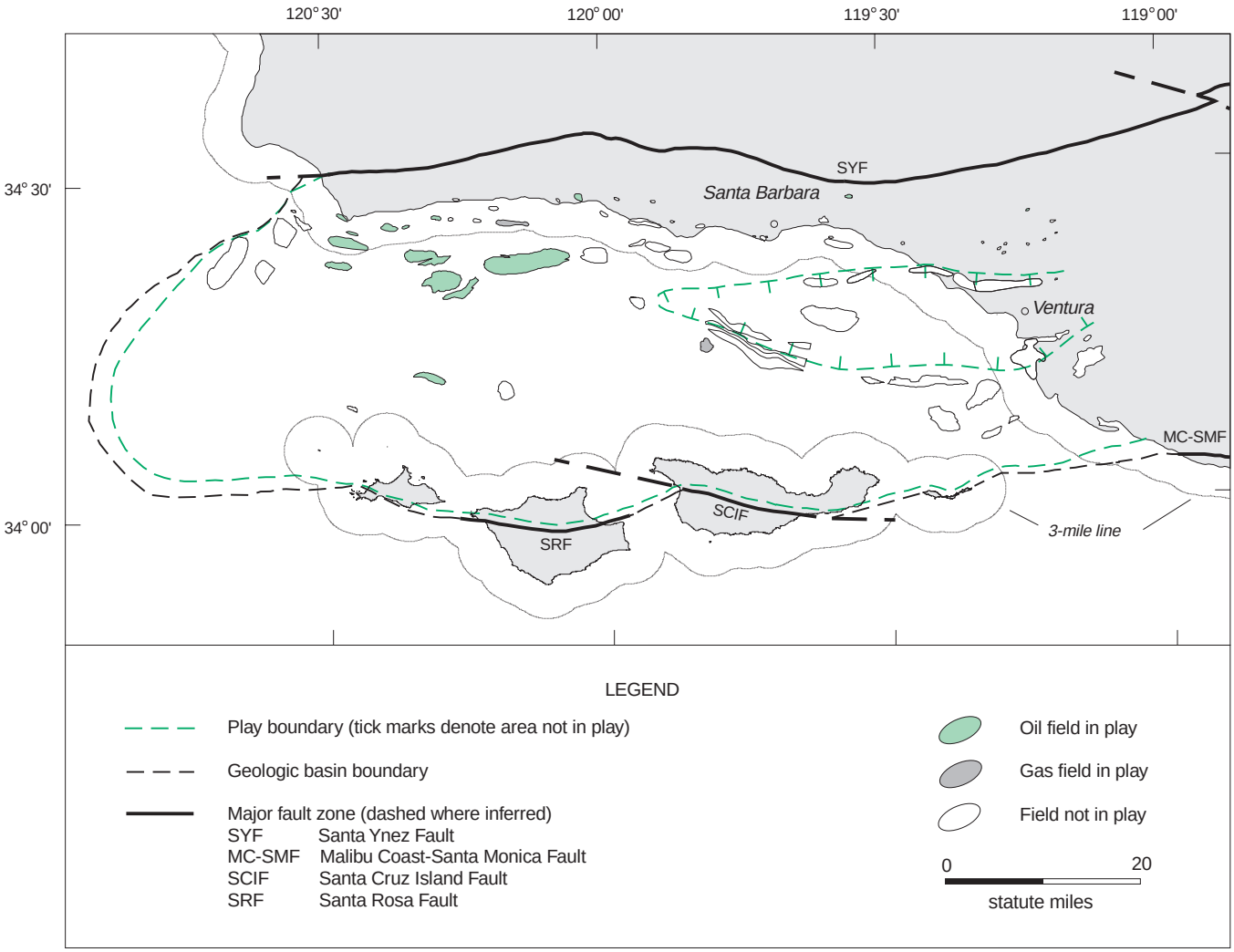


**Figure 83.** *Map of the Gaviota-Sacate-Matilija Sandstone play, Santa Barbara-Ventura basin showing select fields.*

offshore portion of the play encompasses an area of about 1,500 square miles.

## PETROLEUM GEOLOGIC CHARACTERISTICS

Reservoir rocks of this play are primarily fine- to coarse-grained sandstones. Varied depositional environments are exhibited in the reservoirs of this play. Reservoir rocks representative of deep-water turbidites, slope to shelf fans and channels, nearshore bars, and continental and deltaic deposits have been identified. In the most general sense, deep-water facies are more likely to exist in the central and south-central portions of the modern basin. Facies representative of shallow-marine to nonmarine depositional environments are more likely to be found in the north and east parts of the basin.

Relatively few offshore wells penetrate completely through the Eocene section, so its true thickness is not well constrained. The thickest section in this play is estimated (from well correlations and seismic profiles) to exceed 15,000 feet. More commonly, the section ranges from 3,000 to 8,000 feet thick.

The oil and gas reservoired in this play are from multiple sources. Likely source rocks include organic-rich, fine-grained sequences within the Anita Shale (Juncal Formation) and Cozy Dell Shale. These rocks are probably the source of high-gravity, low-sulphur, paraffinic-naphthenic oils. Cretaceous(?)- and Eocene-aged rocks are a probable source of wet gas and condensate in this play. Oils typical of Miocene source rocks (medium to low gravity, sulphur-rich, and asphaltic) also exist in some reservoirs of this play. It is likely that mixed-source accumulations exist as well.

Most petroleum accumulations in this play have been discovered in reservoirs of the Gaviota, Sacate, and Matilija Formations. A few accumulations are

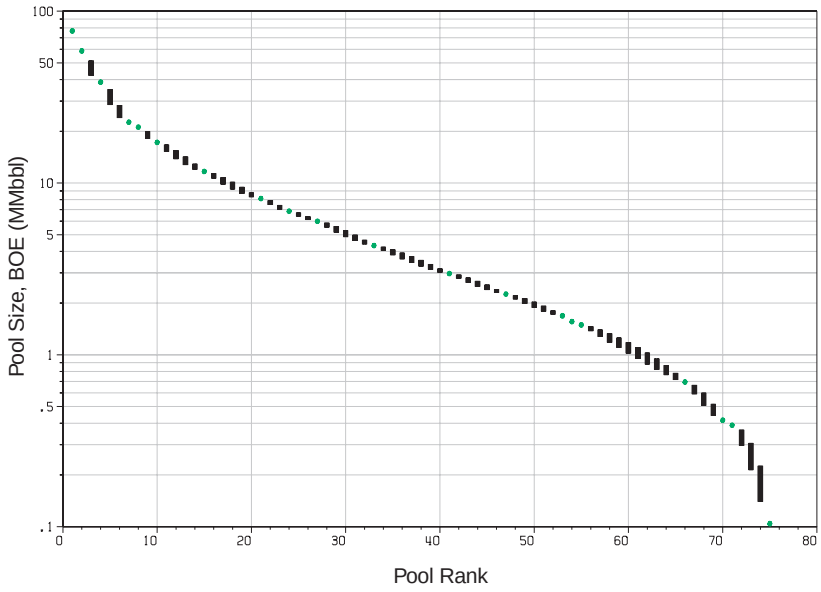


**Figure 84.** *Pool-size rank plot of estimated conventionally recoverable resources of the Gaviota-Sacate-Matilija Sandstone play, Santa Barbara-Ventura basin. Sizes of discovered pools are shown by dots. Sizes of undiscovered pools are shown by bars; the top and bottom of a bar represent the 25th- and 75th-percentile values of a probability distribution, respectively.*

also known from the sandy Camino Cielo Member of the Juncal Formation, sandstones within the Cozy Dell Shale, and the Llajas Formation. Surficial seepage of oil and gas from these rocks occurs at several locations onshore.

Based on analysis of known accumulations, traps within this play are predominantly anticlines, faulted anticlines, and fault blocks. Entrapment may occur less commonly along permeability barriers and angular unconformities.

## DISCOVERIES

Relatively few fields in the Santa Barbara-Ventura basin contain petroleum in only Eocene to lower Oligocene reservoirs; most of these accumulations occur in conjunction with other (most typically Sespe-Alegria-Vaqueros Sandstone) plays. The largest productive accumulations in the play include the Molino Offshore gas field ("Matilija" zone; discovered 1983; 39 MMBOE), Bardsdale field (Llajas zone; 1936; 12 MMBOE), Shiells Canyon field (Llajas zone; 1959; 6 MMBOE), and Capitan field (Gaviota zone; 1945; 4 MMBOE). Other undeveloped accumulations exist in this play, some of which have been identified offshore. Two of these undeveloped onshore accumulations may exceed the Molino Offshore gas field ("Matilija" zone) in size. The earliest production of oil from this play, at Toro Canyon, occurred in the 1880's.

For the purpose of resource assessment, it was assumed that the largest accumulation in the play has been discovered. However, this is a conservative assumption given the minimal exploration history of this play in the Santa Barbara Channel. For example, Eocene sandstones are the primary reservoir at the Rio Vista gas field (>550 MMBOE) in the Sacramento basin and the Coalinga East Extension oil field (>540 MMBOE) in the San Joaquin basin.

## RESOURCE ESTIMATES

### Undiscovered Conventionally Recoverable Resources

Estimates of undiscovered conventionally recoverable resources in the entire play have been developed using the discovery assessment method with pool-size data from 20 onshore and offshore discovered accumulations in the play. Estimates of undiscovered resources in the Federal offshore portion of the play were subsequently calculated using a subjective area-proportionality factor. Select data used to develop the resource estimates are shown in appendix C.

As a result of this assessment, the entire play is estimated to contain 187 MMbbl of oil (including oil and condensate) and 880 Bcf of gas (including associated and nonassociated gas) (mean estimates). This volume of undiscovered conventionally recoverable resources may exist in 55 pools with sizes ranging from approximately 140 Mbbl to 50 MMbbl of combined oil-equivalent resources (fig. 84). Of these, 10 pools may exceed 10 MMBOE.

The Federal offshore portion of the play is estimated to contain approximately 65 percent of these undiscovered conventionally recoverable resources, which is 122 MMbbl of oil (including oil and condensate) and 572 Bcf of gas (including associated and nonassociated gas) (mean estimates). The low, mean, and high estimates of resources in the Federal offshore portion of the play are listed in table 23.

# Cretaceous-Paleocene Sandstone Play

## Play Definition

The Cretaceous-Paleocene Sandstone play of the Santa Barbara-Ventura Basin province is an established play in which oil, associated gas, and nonassociated gas have been discovered. However, there is a paucity of geologic information regarding the play, and its location and petroleum geologic characteristics are poorly understood. Nevertheless, interest continues in this play, which has an important, gas-prone analog in the Sacramento basin.

## Discoveries

A total of 673 Mbbl of oil and 388 MMcf of associated gas have been produced from two fields in the onshore part of the basin. Additionally, an estimated 480 Mbbl of condensate and 12 Bcf of nonassociated gas have been discovered at the Santa Rosa gas field in the Federal offshore area.

## Geologically Analogous Areas

The Cretaceous and Paleogene rocks of the Sacramento, San Joaquin, and Santa Barbara-Ventura basins of California were once part of a continuous forearc basin along the west coast of the North American continent. Because of wide-ranging depositional and sedimentological similarities, these rocks have been collectively termed the "Great Valley Sequence."

The Sacramento basin contains over 100 known gas and high-gravity oil accumulations in formations analogous to this play of the Santa Barbara-Ventura basin. The Grimes gas field (discovered 1960; 660 Bcf), Willows-Beehive Bend gas field (1938; 380 Bcf), and Lindsey Slough gas field (1962; 300 Bcf) represent large, structural and stratigraphic accumulations in Paleocene and Cretaceous reservoirs. The Brentwood field (1962; 9.5 MMbbl and 60 Bcf) is the largest oil accumulation in the Sacramento basin.

Elsewhere in California, outside of the Sacramento basin, a few small oil, condensate, and gas discoveries have been made in Cretaceous- and Paleocene-aged reservoirs. The Helm oil field (1941) in the San Joaquin basin may ultimately produce about 10 MMbbl of oil and condensate and about 60 Bcf of gas from Cretaceous and Paleocene zones. The Oil City area of the Coalinga field (1885; 2.5 MMbbl) was the first area from which petroleum was produced from Great Valley Sequence formations.

## Resource Assessment

This play was not formally assessed. It is not unreasonable to speculate that accumulations similar to or larger than those found in the Sacramento and San Joaquin basins might exist in this largely unexplored play of the Santa Barbara Channel.