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Dr. Robert S. Yeats

The Santa Barbara-Montecito and Goleta basins are structurally continuous fault-controlled Pleistocene basins containing up to 3000 feet (925 m) of marine Pleistocene Santa Barbara Formation which were deposited on previously deformed Sisquoc and older strata. Structures subcropping against the unconformity at the base of the Santa Barbara Formation show that pre-basin deformation was mainly by folding. In addition, high-angle reverse faulting occurred along the Cameros, Goleta, and Modoc faults prior to Santa Barbara deposition in the Goleta basin. These are the oldest faults in the study area.

Deposition of the Santa Barbara Formation began less than 1.2 Ma ago. Post-Santa Barbara (post-basin) deformation includes disharmonic folding of incompetent Miocene strata above broad folds in competent Oligocene strata, as displayed in the Elwood oil field and La Goleta gas field, and reverse faulting along several south-dipping faults of large displacement. The More Ranch fault, which juxtaposes Sisquoc and older strata against the Santa

Barbara and "Pico"(?) Formations, displaces a 40,000 year old marine terrace, forms a north-facing eroded fault scarp, and marks the southern edge of the Goleta basin. The fault dips more than 80° south and displays up to a maximum of 2000 feet (610 m) vertical separation.

The fault in the area with the largest amount of vertical separation, is the Coal Oil Point fault of post-Sisquoc age. This fault fails to reach the surface even though vertical separation of the Oligocene Vaqueros Formation is as great as 5400 feet (1650 m). Comparison with other faults in the area suggests that this fault belongs to the set of south-dipping, east-trending, Quaternary reverse faults that are characteristic of the coastal basins adjacent to the central Santa Ynez Mountains.

All post-basin faults disrupt late Pleistocene strata and are potentially active. Other post-basin faults include the Mesa fault, which may link the More Ranch and Rincon Creek faults, the Lavigia fault which cuts older alluvium, and the San Jose fault which forms a north-facing scarp in late-Pleistocene fanglomerate.

Distribution of aftershocks and focal mechanism solutions of the 1978 Santa Barbara earthquake suggest a gently north-dipping fault plane which would be unrelated to any of the faults exposed at the surface in the study area. However, the linear pattern of aftershock epicenters is parallel to the Mesa and Mission Ridge-Arroyo Parida faults; if the alternate south-dipping nodal plane is the correct solution then the earthquake could have originated on a member of the south-dipping fault set.

SURFACE AND SUBSURFACE GEOLOGY OF THE SANTA BARBARA-GOLETA METROPOLITAN AREA, SANTA BARBARA COUNTY, CALIFORNIA

by

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INTRODUCTION

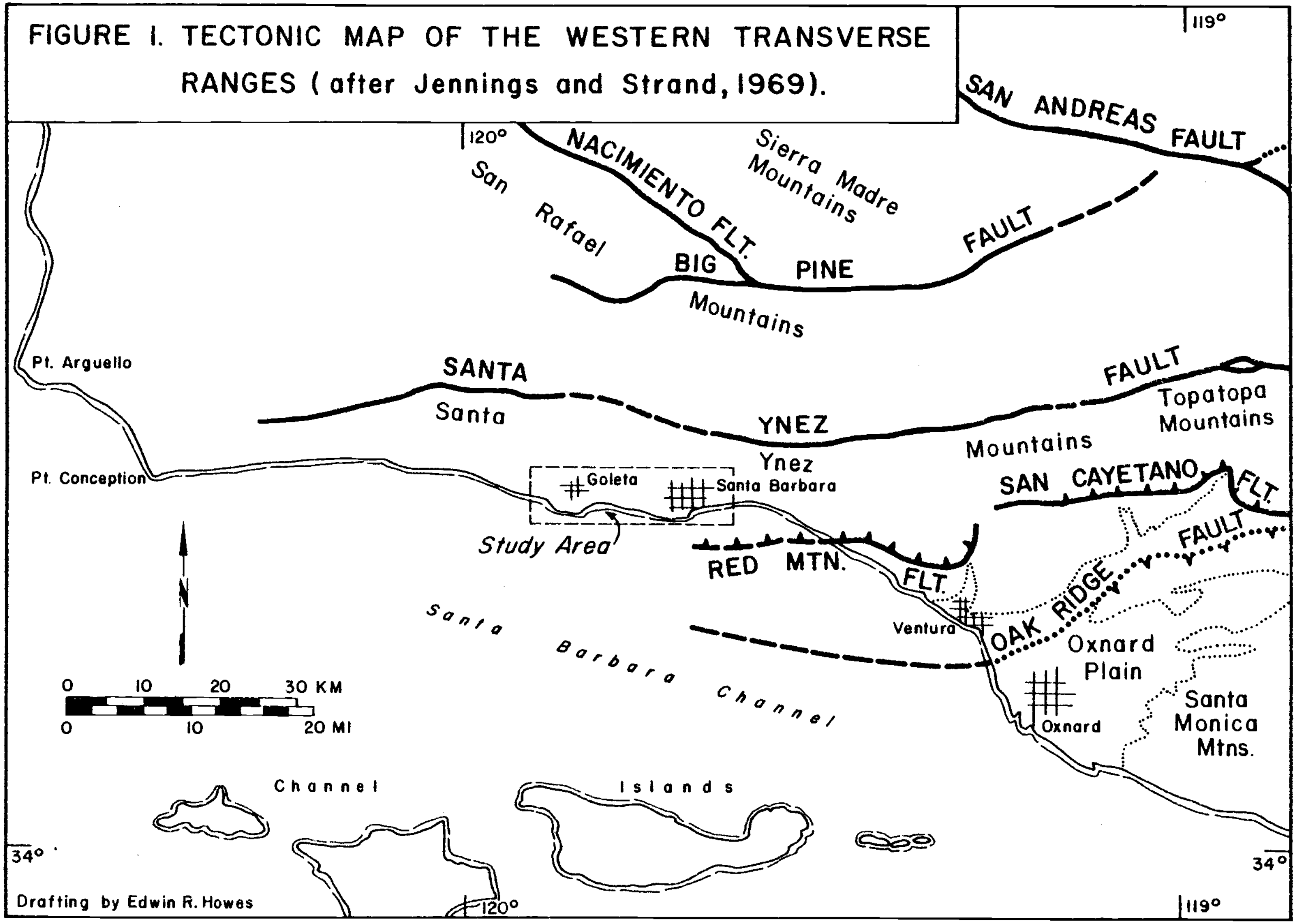
Regional Setting

The study area is located within the western Transverse Ranges along the northern margin of the Santa Barbara Channel (Figure 1) and includes parts of the Santa Barbara, Goleta, and Dos Pueblos 7.5 minute quadrangles of the U.S. Geological Survey. The area is bounded on the north by the central Santa Ynez Mountains, and includes the cities of Santa Barbara, Goleta and Montecito (Plate I).

The coastal area of the central Santa Ynez Mountains has been the site of virtually continuous deposition throughout much of the Cenozoic. An unconformity at the base of the Plio-Pleistocene sequence truncates upper Miocene and older strata and marks the end of this long interval of deposition. It represents a significant change in the depositional/tectonic regime of the central Santa Ynez coastal area. During this interval rates of vertical displacement accelerated throughout southern California such that they were greatest in the last million years (Yeats, 1978).

In the central Santa Ynez coastal area, deformation prior to the deposition of the Pleistocene Santa Barbara Formation was mainly by folding (Jackson, 1982), although in the Goleta area, deformation included folding and localized high-angle reverse

FIGURE I. TECTONIC MAP OF THE WESTERN TRANSVERSE RANGES (after Jennings and Strand, 1969).



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faulting. During the Pleistocene the central Santa Ynez coastal area was isolated from the main Ventura basin, and deformation occurred along east-trending, south-dipping reverse faults and through disharmonic folding of incompetent Miocene strata above broadly folded competent Oligocene strata.

Purpose and Scope of Study

The major purpose of this study is to determine the movement history of potentially active, south-dipping reverse faults, and to discern the fault bedding plane geometry at depth in order to predict the type of earthquake hazard (seismic shaking versus ground rupture) posed by these faults to the highly urbanized Santa Barbara-Goleta area.

Because of the presence of oil and gas fields in this area (Figure 2), the subsurface geology is extensively documented by oil well data which provide an excellent data base for the subsurface investigation of potentially active faults. This report is part of an overall subsurface study of the potentially active faults between Ventura and Goleta now being conducted at Oregon State University under Robert S. Yeats as part of the U.S.G.S. Earthquake Hazard Reduction Program. It is an extension of a study of the Carpinteria area recently completed by Jackson and Yeats (1982).

Methods of Study

A geologic map was compiled from various published reports and from unpublished masters and Ph.D. theses, engineering geology reports, private consulting reports, and industry maps. Field checking and additional mapping were performed by the writer during 1980 and 1981, aided by aerial photos borrowed from Texaco, Inc.

Subsurface data for the 235 oil wells used in this report were obtained from the California Division of Oil and Gas and from various oil companies. Water well data were taken from several ground-water studies, and engineering and consulting reports were obtained from the University of California, Santa Barbara and from the City of Santa Barbara.

These data were used to construct 15 cross sections (12 included as part of this report), structure contour maps of the top of the Vaqueros and of the base of the Pleistocene, and a paleogeologic map of the unconformity at the base of the Pleistocene. Plate II shows the surface locations of the oil, gas, and water wells that were used in this report; these are listed in the appendix.

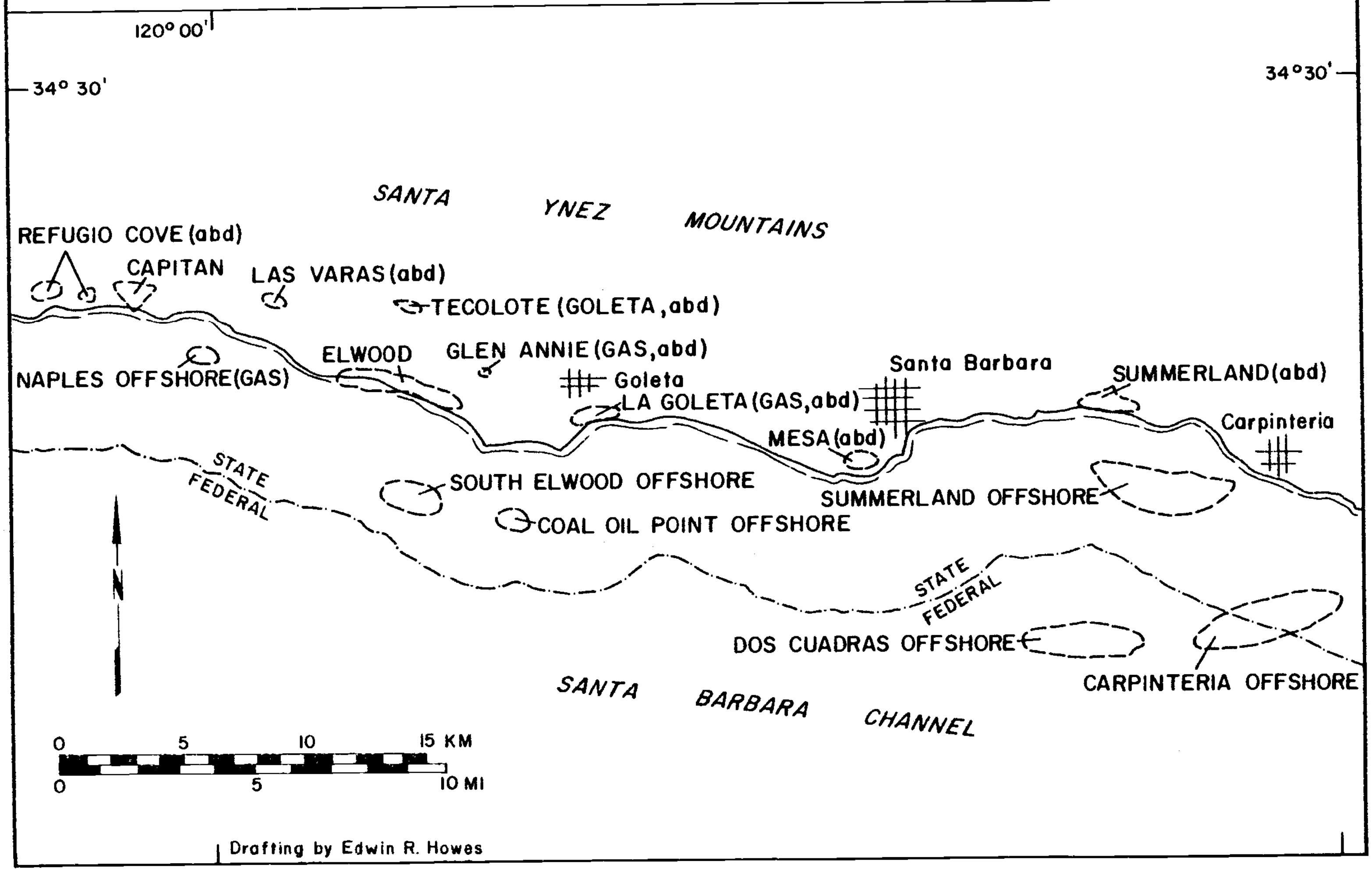
Previous Work

One of the earliest regional studies which included the study area was by Watt (1897), who described the oil and gas potential of formations in the coastal area. Reed and Hollister (1936) briefly discussed the geology of the San Rafael and Santa Ynez Mountains. The most comprehensive and detailed map of the area was prepared by Dibblee (1966) who described the geology of the central Santa Ynez Mountains. Other geologic maps of all or part of the area were prepared by Upson (1951), who discussed the water-bearing strata, and by Lian (1952) who mapped the coastal area between Rincon and Santa Barbara Points.

Topical studies relating to the thesis area include: Willis (1925) on the 1925 Santa Barbara earthquake, Hill (1932) on the mechanics of faulting in the Santa Barbara area, U.S. Geological Survey Professional Paper 679 (1969) on the geology, petroleum development, and seismicity of the Santa Barbara Channel Region, Lee et al. (1978) and Corbett and Johnson (1978), on the 1978 Santa Barbara earthquake, Lee and Vedder (1973), Lee et al. (1979), and Yerkes and Lee (1979) on the seismicity of the Santa Barbara Channel, Loel and Corey (1932), Bramlette (1946), Bailey (1947), Orwig (1957), Edwards (1971), and McCracken (1972) on the regional stratigraphy of the formations exposed in the study area, and Kleinpell (1938), Kleinpell and Weaver (1963), Crouch and Bukry (1979), and Poore (1980), on the regional micropaleontology and biostratigraphy of formations exposed in the study area.

Reports of the geology of oil and gas fields in the area

FIGURE 2. MAP OF OIL & GAS FIELDS IN THE SANTA BARBARA AREA, CALIFORNIA (from Yerkes et al, 1969).



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were done for Elwood[1] (Dolman, 1931; Hill, 1943), La Goleta (Swayze, 1943), and Mesa (Dolman, 1938).

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[1] The name Elwood with one l is derived from the name Ellwood. The name was mispelled on an early U.S. Geological Survey map and the mispelled version was erroneously adopted by the California State Division of Oil and Gas as the official name of the Elwood Oil field.

STRATIGRAPHY

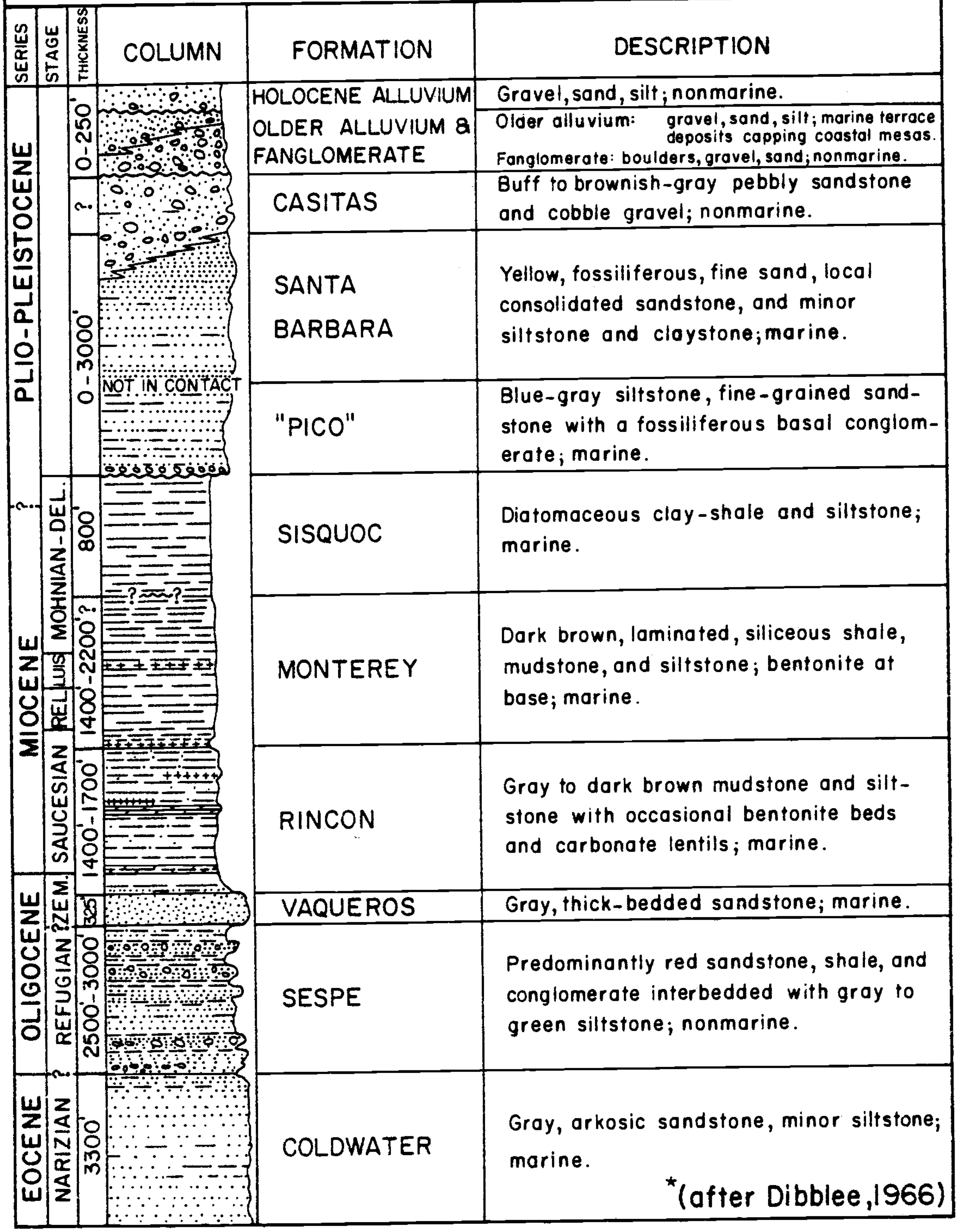
General Statement

Over 13,000 feet (3960 m) of upper Eocene to Holocene strata were encountered in the study area, as measured from the base of the Coldwater Formation (Plate I; Figure 3). The Paleogene strata comprise a structurally competent sequence which includes, in ascending order, the marine, late Eocene Coldwater Formation, the non-marine Oligocene Sespe Formaton, and the marine Oligocene Vaqueros Formation (Edwards, 1971).

Neogene marine strata conformably overlie the Vaqueros Formation and represent a structurally incompetent sequence of mudstone and shale. This sequence includes the late Oligocene-early Miocene Rincon Formation, the late-early to late Miocene Monterey Formation, and the late Miocene to early Pliocene Sisquoc Formation.

Deposition of the Sisquoc Formation came to an end during the early Pliocene, when the entire region was uplifted and eroded (Dibblee, 1966). The "Pico" and Santa Barbara Formations were deposited as the Plio-Pleistocene sea transgressed over the subsiding erosional surface of the coastal plain. The Santa Barbara Formation grades upward and laterally into the non-marine Pleistocene Casitas Formation, which was deposited during southward progradation of an alluvial fan complex into the Montecito and Carpinteria basins (Dibblee, 1966).

FIGURE 3. GENERALIZED STRATIGRAPHIC SECTION OF COASTAL AREA NEAR SANTA BARBARA, CALIF.*



SERIES	STAGE	THICKNESS	FORMATION	DESCRIPTION
PLIO-PLEISTOCENE		0-250'	HOLOCENE ALLUVIUM	Gravel, sand, silt; nonmarine.
			OLDER ALLUVIUM & FANGLOMERATE	Older alluvium: gravel, sand, silt; marine terrace deposits capping coastal mesas. Fanglomerate: boulders, gravel, sand; nonmarine.
		?	CASITAS	Buff to brownish-gray pebbly sandstone and cobble gravel; nonmarine.
		0-3000'	SANTA BARBARA	Yellow, fossiliferous, fine sand, local consolidated sandstone, and minor siltstone and claystone; marine.
			"PICO"	Blue-gray siltstone, fine-grained sandstone with a fossiliferous basal conglomerate; marine.
? MIOCENE	MOHNIAN-DEL.	800	SISQUOC	Diatomaceous clay-shale and siltstone; marine.
	MOHNIAN LUIS REL.	1400-2200'?	MONTEREY	Dark brown, laminated, siliceous shale, mudstone, and siltstone; bentonite at base; marine.
	SAUCESIAN	1400-1700'	RINCON	Gray to dark brown mudstone and siltstone with occasional bentonite beds and carbonate lentils; marine.
OLIGOCENE	?ZEM.	325	VAQUEROS	Gray, thick-bedded sandstone; marine.
	REFUGIAN	2500-3000'	SESPE	Predominantly red sandstone, shale, and conglomerate interbedded with gray to green siltstone; nonmarine.
EOCENE	? NARIZIAN	3300'	COLDWATER	Gray, arkosic sandstone, minor siltstone; marine.

*(after Dibblee, 1966)

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Unconsolidated, elevated, and dissected Quaternary deposits include fanglomerate, older alluvium, and marine terrace deposits. Holocene alluvium now covers much of the valley floor (Plate I).

Coldwater Formation

The Coldwater Formation was described by Kew (1924) at the type locality in Coldwater Canyon, near Fillmore, Ventura County. This unit, previously known as the Coldwater Sandstone, was elevated to formation status by Vedder (1972).

The Coldwater Formation crops out along the southern flank of the Santa Ynez Mountains. In Mission Canyon, just north of Santa Barbara, the Coldwater is 3300 feet (1005 m) thick and consists of hard, thick-bedded, arkosic sandstone which is interbedded with minor argillaceous siltstone (Dibblee, 1966). The Coldwater Formation overlies the Cozy Dell Shale.

The upper Coldwater was encountered in several test wells drilled in the abandoned Goleta oil field and in two wildcat wells (numbers 4 and 67, Plate II) drilled near Santa Barbara. Subsurface data indicate that the Coldwater-Sespe contact is gradational through an interval as thick as 150 feet. In this transition zone, the hard gray sandstone and blue-gray claystone and siltstone which characterize the upper Coldwater alternate with streaks of red sandstone and claystone of the lower Sespe (Plate V). A prominent oyster bed which occurs near the base of the transition zone is used in this report to mark the Coldwater-Sespe contact. The Coldwater contains megafossils which indicate a late Eocene age (Lian, 1952; Dibblee, 1966).

Sespe Formation

Concordantly overlying the Coldwater Formation is the nonmarine Sespe Formation. Kew (1924) described this formation at the type locality in lower Sespe Creek near Fillmore, Ventura County. The Sespe crops out along the northern border of the study area, and at several localities south of the Mesa fault including one where it is unconformably overlain by the type section of the Santa Barbara Formation (Plate I). The Sespe subcrops against the base of the Santa Barbara Formation north and south of the Mesa fault (Plate III). In the Smarkland Hotel water well (T4N, R27W, sec 17; Plate II) located north of the Mesa fault, the Sespe(?)-Santa Barbara contact was encountered between 370 and 385 feet depth (Dibblee, 1966).

The Sespe Formation is composed of interbedded red conglomerate, sandstone, and claystone, with subordinate beds of green claystone and buff sandstone. The Sespe changes gradually westward from a thickness of 3450 feet (1050 m) north of Santa Barbara (Dibblee, 1966), to a thickness of 2100 feet (640 m) in the subsurface west of the Goleta oil field. The Sespe is assigned to the Oligocene on the basis of its stratigraphic position between fossiliferous marine strata. Limited oil production from the Sespe has occurred in the Elwood and Goleta oil fields (Figure 2).

Vaqueros Formation

The type locality of the Vaqueros Formation is along Vaqueros Creek, Monterey County (Hamlin, 1904). This was extended by Arnold (1907) to a marine unit of similar age and lithology in the Santa Ynez Mountains. The Vaqueros concordantly overlies the Sespe Formation and crops out discontinuously along the northern edge of the study area. Two small outcrops of this formation occur southwest of Santa Barbara (Plate I).

In the Santa Barbara-Goleta area the Vaqueros Formation is composed of massive to thick-bedded, hard, fine- to medium-grained, arkosic sandstone. The thickness of this formation is uniform in the Santa Ynez Mountains and averages about 300 feet (90 m), with a gradual increase from east to west. Subsurface thicknesses are variable but generally decrease to the south. For example, in wells 194 and 189 (Plate II) the Vaqueros is about 400 feet (122 m) thick, whereas to the south, in wells 129 and 229, the Vaqueros thins to 150 feet (46 m) and 75 feet (23 m) respectively. The Vaqueros is about 320 feet (98 m) thick in the Elwood oil field, where it is the main producing zone (Plate V).

The Vaqueros contains a microfauna of the Zemorrian stage of Kleinpell (1938). Patet (1972) analyzed core samples from well 189 and assigned a late Zemorrian age to the Vaqueros based on the occurrence of *Siphogenerina mayi* and *Angulogenerina occidentalis* about 138 feet (42 m) below the Vaqueros-Rincon contact. The Vaqueros represents a dynamic-shelf deposit which was extensively winnowed and reworked by wave action and longshore drift, as suggested by its arkosic composition and by the occurrence of megafossils.

As shown in Plate III, the Vaqueros subcrops against the Pleistocene unconformity south of the Mesa fault and beneath the Santa Barbara-Montecito basin, north of the Mesa fault. The Vaqueros subcrop against the Pleistocene unconformity beneath the Santa Barbara-Montecito plain must occur north of the Sespe(?)-Santa Barbara contact in the Smarkland Hotel water well, and south of the outcrop of Rincon Formation on the south side of Mission Ridge (Plate I). This is similar to the Carpinteria basin (Jackson, 1982; Figure 16), but is different than the Goleta basin where the Vaqueros is generally subparallel to the Goleta pre-basin unconformity (Plates V-XII).

Rincon Formation

Conformably overlying the Vaqueros is the Rincon Formation, which was described and named by Kerr (1931) at its type locality in Los Sauces Creek, Ventura County. The Rincon crops out along the northern borders of the Goleta and Santa Barbara-Montecito valleys, and in the hills south-southwest of Santa Barbara (Plate I).

The Rincon Formation is composed of blue-gray to dark brown, massive to poorly bedded mudstone, with occasional concretionary lenses or interbeds of hard, dense dolomite. The dolomite concretions, represented on electric logs by sharp resistivity "spikes," give the Rincon a distinctive electric log character (Plate XIV).

The Rincon is between 1600 (490 m) and 1700 feet (520 m) thick in the Santa Barbara coastal area. Anomalous thicknesses are common and result from flow folding of the incompetent, ductile mudstone.

The Rincon contains microfaunas of the upper Zemorrian and Saucesian stages of Kleinpell (1938) and was deposited at outer shelf to bathyal depths (Edwards, 1971; Patet, 1972). Rincon deposition began after rapid subsidence essentially "froze" Vaqueros deposition such that there are little or no transitional neritic or upper bathyal microfaunas near the contact. Rincon deposition starts out at maximum depth and shallows upward (Edwards, 1971).

Monterey Formation

The type locality of the Monterey Formation is located in Monterey County (Bramlette, 1946). Within the study area, the Monterey crops out along much of the coastal and nearshore area and the foothills of the Santa Ynez Mountains north of the Goleta Valley (Plate I). Dibblee (1966) subdivided the Monterey into a lower unit consisting of soft, fissile, punky shale with subordinate hard siliceous interbeds and an upper unit consisting of hard, brittle, organic, porcellaneous, siliceous shale. Like the Rincon, the Monterey is structurally incompetent so that the normal stratigraphic thickness is obscured by flow folding. The true thickness is between 1400 (427 m) and 2200 feet (670 m) in the study area.

The base of the Monterey Formation is marked by a prominent bentonite bed which is rarely exposed at the surface, but is an excellent electric log marker in the subsurface. In wells where the bentonite bed is missing or indistinguishable, the Rincon-Monterey contact is picked by an abrupt change from the "railroad track" electric log character of the Rincon to the "sawtooth" electric log character of the Monterey (Plate XIII).

The Monterey contains microfaunas of the Saucesian, Relizian, Luisian, Mohnian, and possibly Delmontian stages of Kleinpell (1938), although the validity of the Delmontian as a stage was challenged by Ingle (1967) and Pierce (1972).

Sisquoc Formation

Diatomaceous mudstone and siltstone exposed along the coast from the Elwood oil field eastward to Hope Ranch (Plate I) were correlated to the Sisquoc Formation by Dibblee (1966). The Sisquoc is incompletely exposed in the study area; only the lower 1000 feet (305 m) are present below marine Quaternary deposits. The Sisquoc consists of soft, brown to olive-gray, diatomaceous mudstone and siltstone, which contain abundant diatom debris, sponge spicules, and radiolarians. The contact with the Monterey Formation is gradational, although local unconformities are reported by Dibblee (1966).

The Sisquoc is probably of late Miocene-early Pliocene age, and it is generally referred to the Delmontian stage, although calcareous forams are scarce. This unit is the youngest of the incompetent mudstones and shales overlying the Vaqueros Formation (Figure 3).

"Pico" Formation

A localized unit composed of sandy siltstone, fine-grained sandstone, and a fossiliferous, basal conglomerate is exposed in the sea cliffs about 1 1/4 miles (2 km) east of Goleta Beach (Plate I), where it unconformably overlies the Sisquoc and Monterey Formations. This unit was described by Upson (1951) and tentatively referred to as "Pico" by Dibblee (1966). "Pico" is retained in quotes because the unit is not directly traceable to the type section, and its shallow water depositional environment is different from the turbidity current sandstones of the Pico in the Ventura area.

An incomplete sequence about 330 feet (100 m) thick is exposed in the sea cliffs, and this is overlain unconformably by marine terrace deposits. Considerably thicker, but still incomplete "Pico" sections, were encountered in the subsurface. In well 92, about 800 feet (245 m) of "Pico" was encountered below the More-4 fault (Plate XI). The "Pico" may underlie the Santa Barbara Formation in the Goleta basin; however, the two formations could not be distinguished in the subsurface.

A molluscan fauna collected from the surface section was considered by Woodring (in Upson, 1951) to be late Pliocene in age.

Santa Barbara Formation

The term Santa Barbara Formation was first applied informally by Smith (1919), to fossiliferous sandstone and siltstone exposed in the hills south of the City of Santa Barbara. The term was first used formally by Woodring et al. (1940). The type section (located on Plate I) was described by Dibblee (1966).

The original stratigraphic thickness of the Santa Barbara Formation is unknown because the upper part has been removed by erosion. A maximum exposed thickness of about 500 feet (150 m) is found south and southwest of Santa Barbara (Dibblee, 1966). Substantially thicker sections occur in the subsurface. In well 94, the base of the Santa Barbara was penetrated at 2940 feet depth. This interval may include beds equivalent to the older "Pico" Formation as well as the Santa Barbara.

The Santa Barbara Formation at Ventura has been correlated with the type section in Santa Barbara based on a megafauna characterized by *Pecten bellus* (Bailey, 1943). In the Ventura area, the Bailey ash, dated as 1.2 Ma by Izett et al. (1974) occurs in the uppermost Pico Formation, just below the base of the Santa Barbara Formation. This implies a maximum age of 1.2 Ma for the Santa Barbara strata near Ventura containing *Pecten bellus*. Based on the assumption that the basal Santa Barbara beds at the type section are not time-transgressive with respect to the basal Santa Barbara beds near Ventura, the Santa Barbara Formation at Santa Barbara is less than 1.2 Ma in age.

Casitas Formation

The nonmarine Casitas Formation was described and named by Upson (1951) at its type locality, near the junction of Casitas and Rincon Creeks, about 12 miles (19 km) east of Santa Barbara. An exposure of about 100 feet (30 m) of pebbly sandstone and cobble gravel is found in the sea cliffs south of the Santa Barbara Cemetery, located between Santa Barbara and Montecito. This unit represents the only surface occurrence of the Casitas within the study area. Here, the Casitas is gently folded at the crest of the Montecito anticline (Plate I). The base of the Casitas is not exposed, and the formation is overlain unconformably by fossiliferous late Pleistocene marine terrace deposits.

In the subsurface, the Casitas was encountered in several water wells in the Montecito area, but was not confirmed in wells to the west. In the Carpinteria basin, the Santa Barbara Formation grades upward and laterally into the Casitas Formation (Jackson and Yeats, 1982). The Casitas was deposited as an alluvial fan complex which prograded southward over the Santa Barbara Formation, and it may underlie at least part of the city of Santa Barbara. The Casitas is generally younger than the

Santa Barbara Formation, but is in part equivalent to the upper Santa Barbara. The Casitas is older than the late Pleistocene marine terrace deposits which unconformably overlie it.

Fanglomerate and Older Alluvium

Fanglomerate occurs along the northern border of the study area as slightly elevated and dissected piedmont fans which discordantly overlie all older formations (Dibblee, 1966). These fans are composed of poorly sorted cobble gravel and coarse- to fine-grained sand. They have been disrupted by faulting at several locations, including the Mission Ridge area and the hills northeast of the Goleta Valley. Finer grained deposits of older alluvium occur in the valley areas as outwash from these fans and are now buried beneath Holocene alluvial deposits.

The coastal mesas are capped by marine terrace deposits which unconformably overlie deformed Neogene formations. These units typically consist of a fossiliferous basal conglomerate deposited on a wave cut platform overlain by finer grained littoral deposits (Dibblee, 1966). The deposits rarely exceed 60 feet (18 m) in thickness. The age of the terrace underlying the Devereaux-University mesa, located south of Goleta Valley, was estimated as 40,000 years old by amino acid racemization (Wehmiller et al., 1978). The sample locality for this terrace deposit is indicated on Plate I.

Holocene Alluvium

Undissected Holocene alluvium covers most of the valley areas and may be as thick as 225 feet (70 m) in the Goleta Valley (Upson, 1951).

STRUCTURE

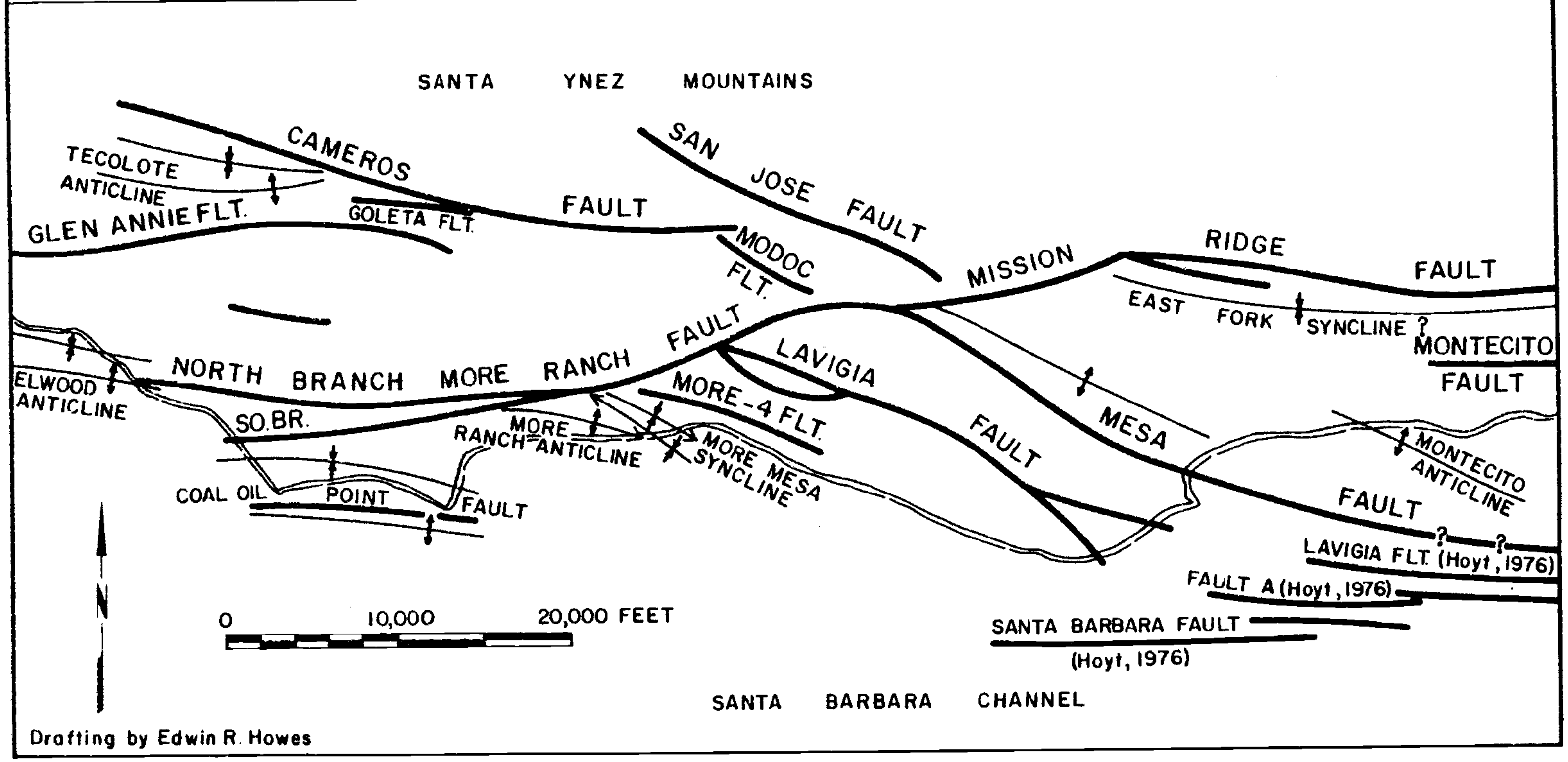
Introduction

The regional structure of the Santa Ynez Mountains is a south-dipping homocline uplifted on the north along the Santa Ynez fault (Figure 1). In the study area, the regional homocline involves Oligocene and Miocene strata at the surface, and it has been modified by Pliocene and Quaternary deformation (Plate I and Figure 4).

The south dip of the Oligocene and Miocene strata controls the orientation of most of the faults in the area. Important to the structural style of the area is the ductility contrast between the competent Oligocene and older sequence and the incompetent Miocene sequence. This results in disharmonic folds which are locally overturned to the north such that the overturned limbs are in some cases attenuated and faulted.

Jackson (1982) was able to separate structures in the nearby Carpinteria basin into those that pre-date the basin and those which formed during and after the time of basin formation. In that area, pre-basin structures are mainly northwest-trending open folds which formed concurrently with uplift along the Santa Ynez regional homocline. Post-basin structures include large displacement reverse faults and asymmetric disharmonic folds. This distinction can be extended to the Santa Barbara-Montecito area as well. However, in the Goleta area, there are several important differences. Here pre-Santa Barbara folds are less extensive,

FIGURE 4. MAJOR STRUCTURES IN THE SANTA BARBARA AREA, CALIFORNIA.



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and pre-Santa Barbara deformation includes both folding and faulting. Post-Santa Barbara structures in the Goleta area are similar to those in the Santa Barbara-Montecito and Carpinteria areas.

Pre-Basin Structures

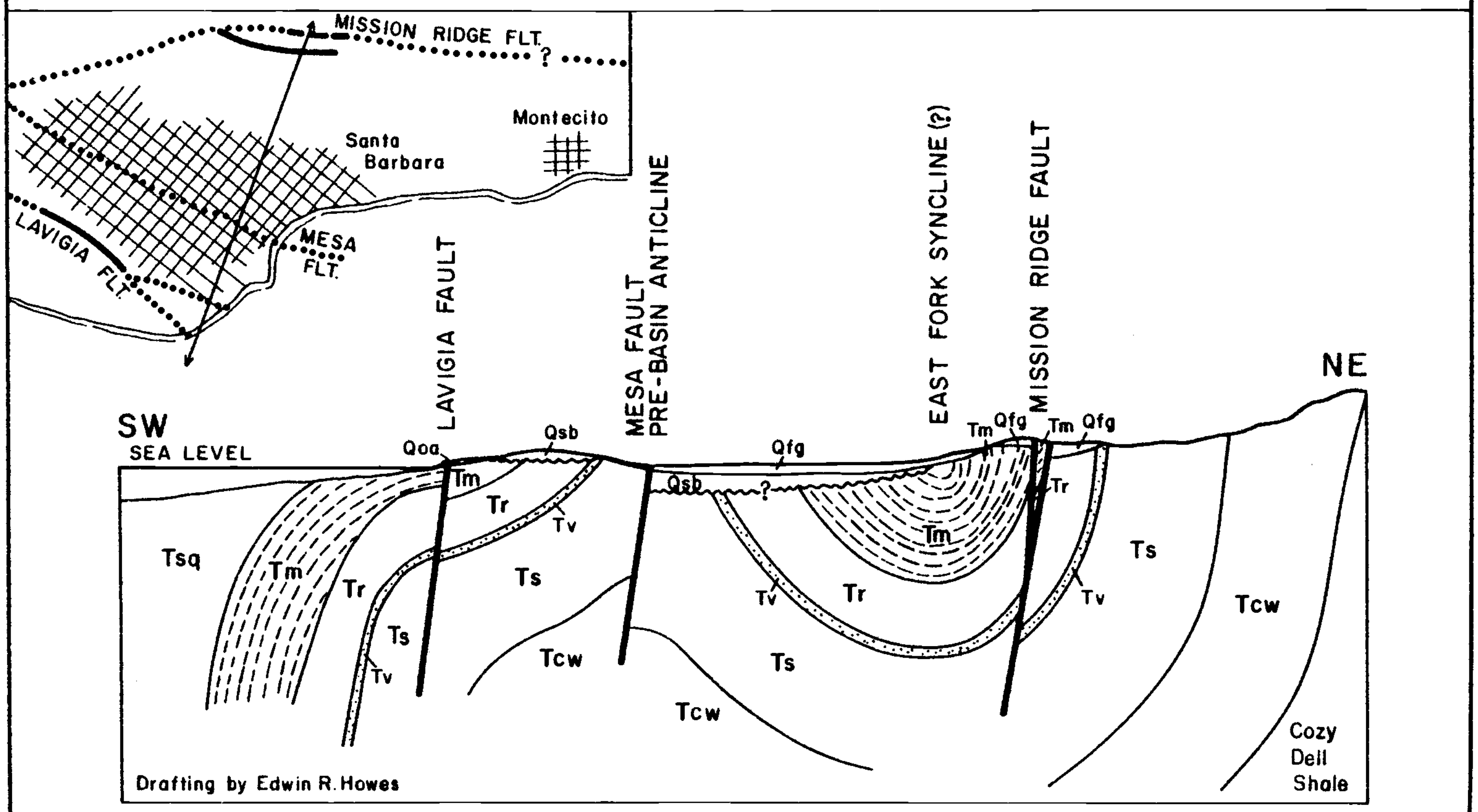
In the foothills north and northeast of Santa Barbara, the strata of the south flank of the Santa Ynez Mountains are inclined steeply south and locally overturned (Plate I). This structure was named the Montecito overturn by Lian (1952), who considered it to be the western analog to the Matilija overturn of Kerr and Schenk (1928), which is located to the east in Ventura County. West of Mission Canyon, the Montecito overturn changes such that all strata dip southward and are right side up (Plate I).

Pre-Santa Barbara structures in the subsurface display a corresponding westerly decrease in the intensity of deformation. In the subsurface of the Carpinteria basin, the basin unconformity was cut on steeply dipping Oligocene and Miocene strata. The subsurface structure of the Santa Barbara-Montecito area is poorly understood because of longstanding drilling restrictions in that area. However, there are sufficient data available to draw some general inferences. Surface mapping near the type section of the Santa Barbara Formation and subsurface data from the Smarkland Hotel water well (Plate III) indicate that in this area the Santa Barbara Formation was deposited unconformably on the Sespe Formation on both sides of the future trace of the Mesa fault. Younger strata are present on Mission Ridge to the north and in the "La Mesa" hills to the south. The resultant subcrop pattern on the paleogeologic map (Plate III) reveals a pre-Santa Barbara anticline which was centered in the vicinity of the present day trace of the Mesa fault (Figures 4 and 5). The amount of uplift and erosion was enough for the removal of all post-Sespe strata. A part of the south flank of this structure is now exposed south of Santa Barbara (Plate I) where the angular discordance between the Sespe and Santa Barbara is 30°. The absence of Sisquoc strata in the subsurface of the eastern Goleta basin suggests that this structure extends west of the Mission Ridge fault as shown on Plate III.

In the hills north of the City of Santa Barbara, the Monterey, Rincon, Vaqueros and Sespe formations crop out from south to north. This requires that either a pre-basin syncline or a south side up fault be present south of Mission Ridge. Jackson (1982) proposed that the north flank of the East Fork syncline can be extended at least to water well 4N-26W-7R1 which encountered steeply dipping, overturned Vaqueros(?) strata beneath older alluvium. The inferred structure in the Mission Ridge area may be the westward continuation of the East Fork syncline, which has been obscured and truncated by displacement on the Mission Ridge fault (Figure 5).

In contrast to the Santa Barbara-Montecito area, the basin

FIGURE 5. DIAGRAMMATIC CROSS SECTION ACROSS MISSION RIDGE AND SANTA BARBARA PLAIN (modified from Dibblee, 1966).



unconformity in the Goleta area was eroded on gently dipping Miocene strata. Throughout most of the basin, the angular discordance between strata above and below the unconformity is less than 20° (Plates VI-XII).

In the area east of Goleta Slough are several west-northwest-trending, southeast-plunging folds within the Sisquoc and Monterey Formations. These folds are probably subsidiary to the More Ranch fault (Dibblee, 1966), and are post-basin structures. However, the subcrop pattern of the Sisquoc-Monterey contact below the "Pico" strata near well 128 suggests the existence of a set of pre-"Pico" folds which trend west-northwest and plunge northwest (Figure 4; Plate IV). A pre-"Pico" age is indicated by the fact that the "Pico" strata are deposited partly on Monterey and partly on Sisquoc strata. The Sisquoc strata preserved in this structure are the only Sisquoc exposed in the sea cliffs from Goleta Beach to beyond Montecito (Plate I).

Pre-Basin Faults in the Goleta Valley

In contrast to the Santa Barbara-Montecito and Carpinteria areas, pre-basin deformation in the Goleta Valley included faulting as well as folding. Pre-basin faulting can be demonstrated for the Cameros, Goleta, and Modoc faults (Plates I and III, and Figure 4).

The Cameros fault, located north-northwest of Goleta (Plate I), was described and named by Hill (1932). Upson later extended this fault eastward below the valley fill on the basis of groundwater level contours and pumping test data. The Cameros fault trends approximately N70°W, with the south block upthrown relative to the north. The fault dip is inferred to be steep because of its straight trace across varied topography (Hill, 1932). The dip of the fault is inferred to be to the south by analogy with other south side up faults in the area. The net slip of the Cameros fault is indeterminate without a piercing point offset, although Hill (1932) suggested a large component of left-lateral displacement. As shown on Plate III, the subcrop of the Monterey-Rincon contact against the Pleistocene unconformity north of well 72 intersects the Cameros fault at two locations. The western intersection displays an apparent left-lateral separation, while the eastern intersection displays an apparent right-lateral separation. These relations are best explained by dip-slip displacement prior to Santa Barbara deposition. Moreover, the outcrop trace and zero contour line of the basin unconformity show little displacement across the fault, indicating that most of the displacement occurred prior to the deposition of the Santa Barbara Formation. As shown on Plate IX, the vertical separation of the Monterey-Rincon contact is about 600 feet (180 m), whereas the separation of the basin unconformity is no more than 100 feet (30 m). Vertical separation of the unconformity increases eastward to approximately 300 feet (90 m) (Plates (III and XI).

The Goleta fault (Plate I) was postulated by Upson (1951) on the basis of anomalous ground-water data. Relations from wells 72 and 82 (Plate IX) support the existence of this fault. Using a dipmeter log near the Rincon-Vaqueros contact in well 72 as a projection guide, it can be seen that the top of the Vaqueros in well 82 is too high, so the Goleta fault is needed to resolve this. In view of the persistent southerly dips of the Vaqueros in this area (Plate IV), a south side up fault is a more reasonable solution than a fold. The subcrop pattern of the Monterey-Rincon contact across the Goleta fault is similar to the relations described for the Cameros fault, and indicates that, like the Cameros fault, displacement along the Goleta fault was mainly dip-slip, with the south side up, and most of the displacement occurred prior to the deposition of the Santa Barbara Formation. Upson (1951) inferred an unspecified amount of post-Santa Barbara displacement on the basis of significant differences in the groundwater levels across the fault. An impermeable barrier in the Santa Barbara Formation, detected by pumping tests, was postulated as the fault. The Goleta fault may merge with the Cameros fault east of well 72.

The Modoc fault, located at the east end of the Goleta Valley (Plate I) was also postulated by Upson (1951) on the basis of anomalous groundwater data similar to evidence utilized for the Cameros and Goleta faults. The trend of this fault is N45°E, as controlled by water wells 4W-28W-12L4 and 12K2 (Upson, 1951) and oil wells 86 and 88 (Plates I and IV). Relations from wells 86 and 88 (Plates IV and XII, cross section I-I') indicate that the northeast block is upthrown relative to the southwest block. The Vaqueros-Rincon contact displays approximately 1300 feet (396 m) of vertical separation, whereas the fault is expressed in the Santa Barbara Formation as an impermeable ground-water barrier. These relations indicate that most of the displacement occurred prior to the deposition of the Santa Barbara Formation.

Coal Oil Point Fault

The Coal Oil Point fault is clearly documented in the subsurface offshore from the Devereaux-University Mesa (see Plates VII, IX, and X). The fault fails to reach the surface although the vertical separation of the Rincon-Vaqueros contact is as great as 5400 feet (1650 m) (Plate IX). This relationship, an apparent consequence of the high ductility contrast between the competent Oligocene strata and the incompetent Miocene strata, is best seen on plates VII, IX, and X. On cross section E-E' (Plate IX) well 101 penetrated the Vaqueros Formation at a depth of 3875 feet and again at 9980 feet depth. The fault was encountered at 3604 feet depth in well 102, and at a depth of 8410(?) feet in well 101. The fault dips 80° south and trends east-west. As shown on plates IX and X, electric log markers from the Monterey and Sisquoc Formations can be correlated across the crest of the Coal Oil Point anticline without any apparent offset. Detailed mapping of the sea-floor by Fischer and Stevenson (1973, Figure 3) revealed no surface trace of this fault (Plate I). The available data are insufficient to document the fault east of Goleta Point or west of Coal Oil Point.

The ages of the fault and related folds are unknown as these structures involve Sisquoc and older strata. The occurrence of subcommercial quantities of oil in the Vaqueros of both the hanging wall block and the foot wall block indicates that the Coal Oil Point anticline pre-dates the fault.

Post-Basin Structures

As regional emergence and deformation continued into the late Pliocene-early Pleistocene, an erosional surface beveled older structures along the coastal margin of the Santa Ynez Mountains. The coastal margin began to subside, and deposition of the Santa Barbara Formation began less than 1.2 Ma ago. Subsidence in the Goleta area may have began earlier, depending on the age and distribution of the "Pico" strata in that area. Structures are designated as post-basinal if they equally deform strata above and below the pre-Santa Barbara unconformity.

More Ranch Fault

The More Ranch fault was first mapped by Hill (1932) as two separate faults, the Elwood fault and the More Ranch fault. This fault was later mapped by Upson (1951) and Dibblee (1966) as one continuous fault which trends east-west and, for much of its length, separates the Goleta Valley from the elevated coastal mesa to the south (Plate I). The fault extends westward from the intersection of the Mesa and Mission Ridge faults, and branches into two strands east of Mescalitan Island. The north, or main branch, raises a discontinuous, north-facing scarp along the northern edge of the Devereaux-University mesa, and at the east end of the Elwood oil field, where it cuts marine terrace deposits (Dibblee, 1966) which have been dated as 40,000 years old by Wehmiller et al. (1978). The fault brings Rincon, Monterey, and Sisquoc strata on the south into fault contact with the "Pico"(?)-Santa Barbara strata on the north (Plates VI-XII).

Vertical separation as measured from the offset Vaqueros-Rincon contact decreases westward. Maximum vertical separation of 2000 feet (610 m) occurs east of Mescalitan Island (Plates IV, XI and XII, cross section G-G'). Northwest of the UCSB campus, vertical separation is approximately 800 feet (245 m) (Plates IV and VII), and separation decreases to less than 400 feet (120 m) north of the Elwood oil field (Plates IV and V).

For most of its length, the fault dips between 75-85° south (Plates VII, VIII, X, and XII, cross section G-G'). Near the Elwood oil field, the dip decreases westward as the fault apparently passes into bedding. In this area, the fault, as exposed in the sea cliffs, dips 45° south within the Monterey Formation (Dibblee, 1966). With the possible exception of the Ellwood area, the north branch of the More Ranch fault cuts across the competent Vaqueros strata, but there is no well control on the fault as it passes into the Sespe Formation.

The south branch of the More Ranch fault is exposed along the west side of the Goleta Slough, where it brings Sisquoc strata on the south into fault contact with the Santa Barbara Formation on the north (Plate I). Trenching operations in the Goleta Slough area have located this fault as far east as Mescalitan Island (Dames and Moore, 1973), beyond which it may merge with the north branch of the More Ranch fault.

Westward from the Goleta Slough, the fault is not topographically expressed as it crosses the Devereaux-University mesa, but it is documented in well 230 (Plate VIII). Prominent east-west photo lineations observed in the marine terrace deposits about one-half mile (0.8 km) north-northwest of Coal Oil Point may mark the surface trace of this fault (Texaco aerial photos, 1928, Job 11, no. 66-68). The fault is exposed in the sea cliffs about three quarters of a mile (1.2 km) northwest of Coal Oil Point where it offsets the 40,000 year old terrace (Dames and Moore, 1973).

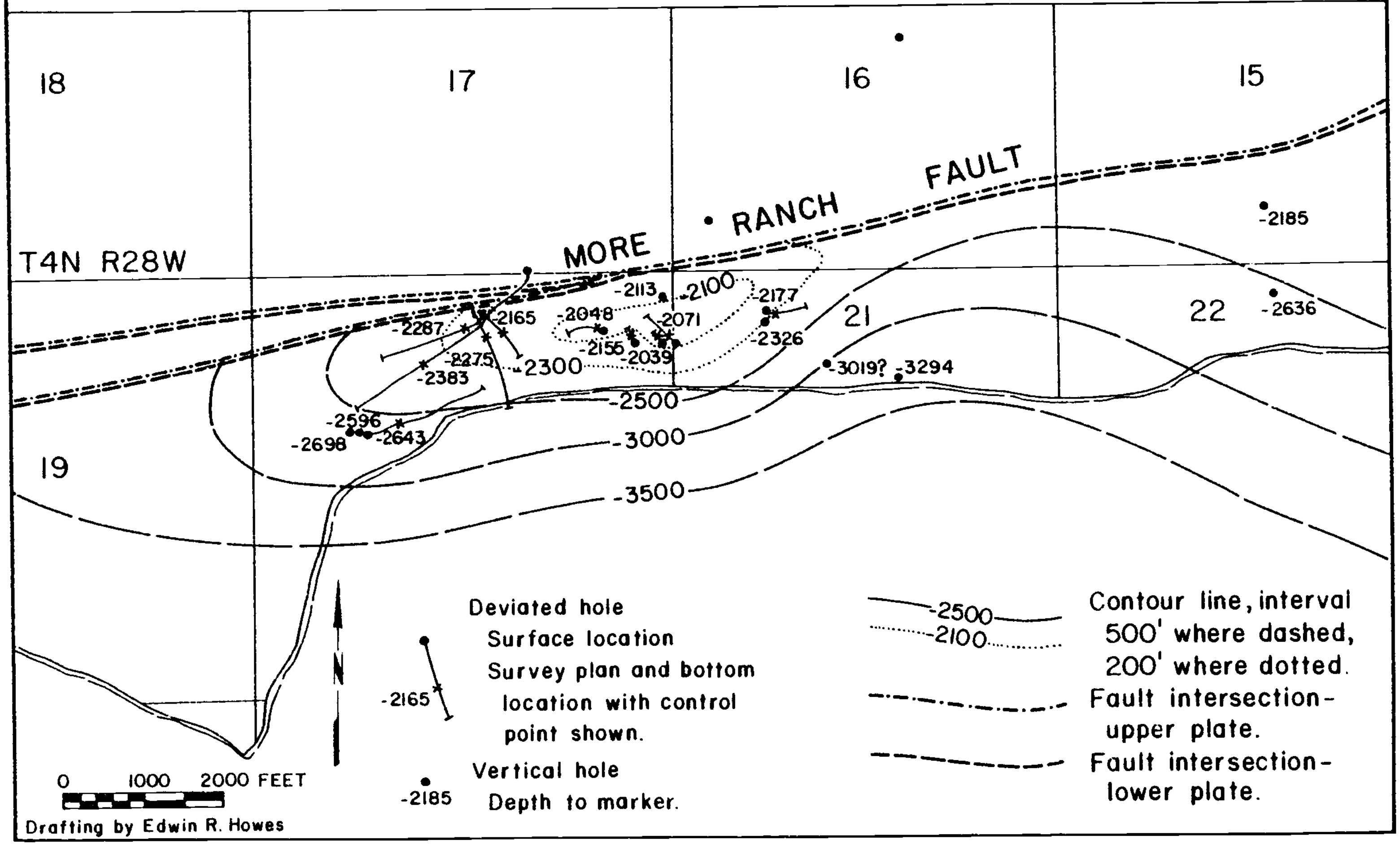
In the subsurface, the fault cuts well 230 at a depth of 4810 feet. At this depth the well passed from the middle Rincon Formation into the lower Monterey Formation (Plate VIII). The vertical separation, as indicated by relations in this well, is about 1000 feet (305 m). Relations in cross section F-F' (Plate X), which crosses the west side of the La Goleta gas field, indicate approximately 700 feet (215 m) of vertical separation. This suggests that the vertical separation on the south branch decreases eastward as it approaches the north branch. West of well 230, there is little subsurface control on the south branch as it extends offshore.

More Ranch Anticline

The More Ranch anticline is the producing structure of the La Goleta gas field (Figure 2) which was depleted in 1941 and is now used for gas storage. The Monterey Formation is exposed at the crest and on the southwest limb and dips as much as 75° to the southwest. The fold in the Vaqueros strata is a relatively broad structure with the southwest limb dipping about 20° southwest (Plate IV, XII). Furthermore, comparison of Plates I and IV and Figure 6 indicates that the crest of the fold in the incompetent strata identified by the outcrop pattern of the Monterey-Sisquoc contact and the Rincon structure contours, does not correspond in map position to the crest as defined by Vaqueros structure contours. These relations indicate that the More Ranch anticline is disharmonically folded.

In the footwall block of the More Ranch fault northeast of the More Ranch anticline, "Pico"-Santa Barbara strata were encountered to a depth of approximately 3000 feet (915 m) (Plate III). South of the fault these strata are absent. Along this segment the vertical separation across the More Ranch fault is

FIGURE 6. STRUCTURE CONTOUR MAP, LA GOLETA GAS FIELD: TOP OF THE RINCON FORMATION.



about 2000 feet (610 m) as measured from the offset of the top of the Vaqueros (Plates IV and XII, section G-G'). This suggests that the More Ranch anticline influenced deposition of "Pico"-Santa Barbara strata prior to the formation of the More Ranch fault. The truncation of the Vaqueros contours by the More Ranch fault also suggests a pre-fault age for the More Ranch anticline (Plate IV). Alternatively, these relations may be indicative of lateral displacement along the More Ranch fault.

More-4 Fault and More Mesa Syncline

The More-4 fault is not exposed at the surface, but is documented in well 92 where Relizian strata of the Monterey Formation are thrust over "Pico" strata (Plate XI). The "Pico" was encountered below the fault to 750 feet depth. The fault is inferred to be a north side up fault since Monterey strata are exposed at the surface 400 feet north of well 92. To the south in well 128 "Pico" strata were encountered to 1210(?) feet depth.

The "Pico" strata are folded in the More Mesa syncline (Plate I, Figure 4). This structure contains approximately 1800 feet (550 m) of "Pico" and was formed on previously deformed Sisquoc and older strata. As shown on Plate III the older folds plunge northeast while the More Mesa syncline plunges southwest. The syncline is bounded on the north by the More-4 and More Ranch faults. The structure contours of the base of the "Pico" (Plate III) suggest that the development of this structure was related to movement on the More-4 fault. The fold is truncated by the More Ranch fault which indicates that the More-4 fault and More Mesa syncline are older than the More Ranch fault.

Goleta Basin

The geometry of the Goleta Basin is defined by the basin unconformity. The structure of the basin is that of an asymmetrical faulted syncline which was folded during deposition of the "Pico" (?)-Santa Barbara strata (Plates III and VI-XII). Relations from Plates III and IV indicate that the deepest part of the basin is adjacent to that segment of the More Ranch fault displaying the largest vertical separation as measured from the Vaqueros-Rincon contact. Furthermore, the trend of the basin parallels the trend of the More Ranch fault. This implies that the geometry of the Goleta basin is partially controlled by the More Ranch fault, a relationship similar to that between the Carpinteria basin and the Rincon Creek fault. The Goleta basin is structurally continuous with the Santa Barbara-Montecito basin (Upson, 1951), and together they may be structurally continuous with the Carpinteria basin. This suggests that the More Ranch, Mesa, and Rincon Creek faults are also structurally continuous.

If the slightly older "Pico" strata are present in the Goleta basin, then this would indicate a slightly older age for the Goleta basin relative to the Santa Barbara-Montecito and Carpinteria basins. Relations across the More Ranch fault discussed above, imply that deposition in the Goleta basin may have begun prior to the formation of the More Ranch fault, and that uplift along the More Ranch anticline may represent the initial isolation of the Goleta Basin from the Santa Barbara Channel. Unfortunately, the subsurface data were insufficient to document the predicted southward onlap of the Pleistocene strata over a north-dipping unconformity.

Elwood Anticline

At the west end of the study area, the Elwood anticline is present in the cliffs and exposes sharply folded Monterey strata at the crest. It was this exposure which led to the discovery of the Elwood oil field in 1928. In this structure, the Sisquoc, Monterey, and Rincon Formations are disharmonically folded above the competent Vaqueros and Sespe Formations. At the surface, the Monterey Formation along the south flank dips as much as 70° south, whereas, in the subsurface, the Vaqueros and Sespe strata dip 40° south (Plate V). The eastern half of this fold is in part cut by the north branch of the More Ranch fault (Plates IV and V). This fold is considered a post-basin structure because of its relationship to the More Ranch fault.

Lavigia Fault

The Lavigia fault branches off from the More Ranch fault northwest of the Hope Ranch area (Plate I). Trenching in this area indicates that near the surface the fault dips 38-40° southwest and brings strata of the lower Monterey Formation on the south into fault contact with Quaternary terrace deposits on the north (Weaver, 1979). As the fault trends east-southeast across the Hope Ranch area it brings the Monterey Formation on the south into fault contact with the Santa Barbara Formation on the north, with several minor faults branching off (Plate I). The fault is best exposed in the small valley northeast of Veronica Springs (Plate I) where the Rincon Formation on the south is faulted against the Santa Barbara Formation on the north. Section J-J' (Plate XIII), which passes through this valley, indicates about 450 feet (137 m) of vertical separation. Hoover (1978) estimated a minimum of 600 feet (180 m) of vertical separation on the basis of water well data in the Veronica Springs area. Farther southeast, the fault disappears under the marine terrace deposits of the La Mesa area in the southwest part of the City of Santa Barbara. Although the Lavigia fault cuts similar terrace deposits at Hope Ranch, it could not be demonstrated that the fault cuts the marine terrace deposits in the La Mesa area, nor has it been demonstrated that the terrace truncates the fault. The fault extends eastward across the north side of the Mesa oil field and cuts well no. 7 (Plates IV and XIV, cross section K-K'). In this well the top of the Vaqueros is repeated and vertical separation is about 200 feet (60 m). Minor faulting of the Monterey Formation in the cliffs near Santa Barbara Point may mark the location of this fault as it passes offshore.

Minor faulting in the cliffs south of the La Mesa area (Plate I) and interpretations of the Vaqueros structure contours suggest that a southern strand of the Lavigia fault may branch off to the southeast and pass offshore in the area of minor faulting (Plates IV and XIV, cross section L-L').

The Lavigia fault apparently influenced late Pleistocene and Holocene depositional and drainage patterns in the area southwest of the City of Santa Barbara. As shown on Plate I, fanglomerate occurs only on the north side of the Lavigia fault, and older alluvium (marine terrace deposits) occurs only on the south side, at elevations of 200, 400, and 600 feet. The relations indicate that the Lavigia fault may have controlled the sites of late Pleistocene marine and nonmarine deposition. The occurrence of older alluvium (marine terrace deposits) at 3 different elevations may be related to recurrent movement along the Lavigia fault which may have been accompanied by eustatic sea level changes.

In addition to the main valley areas, Holocene alluvium occurs in two possibly antecedent valleys in the Hope Ranch area (Plate I). In both valleys the width of the alluvial deposits is greatest immediately north of the Lavigia fault. The Laguna Blanca now occupies the wide valley area north of the Lavigia fault in the westernmost of these two valleys (Plate I). These relations indicate that uplift along the Lavigia fault may have partially obstructed the southward flow of these streams and created a ponding effect on the downthrown block. This resulted in deposition of alluvium over a wider area in the valley areas north of the fault and allowed the Laguna Blanca to form.

On the south side of the Mesa oil field, well no. 44 penetrated the Sespe Formation from 2410 feet depth to the bottom of the well at 10,042 feet depth (Plate XIV, cross section K-K'). The Sespe is only about 3000 feet (915 m) thick in this area, so that such anomalous thicknesses are either caused by an abrupt dip increase of the Sespe along a structural hinge line at the northern edge of the Santa Barbara channel, or by a Red Mountain-type, north-dipping reverse fault which cuts well 44 and repeats most of the Sespe.

Mesa Anticline

The Mesa anticline was mapped offshore by Hoyt (1976) from interpretations of seismic profiles and dart core sample. This fold, which exposes Saucesian strata at its crest, trends west-northwest and plunges easterly (Hoyt, 1976). As shown on Plate I, the zero isopach line of unconsolidated sediments (from Hoyt, 1976) is apparently influenced by this fold, which indicates that the anticline was topographically high and possibly undergoing deformation during the Holocene. The onshore extension of this fold is a structural terrace faulted on the north by the Lavigia fault, and it represents the producing structure of the Mesa oil field.

Montecito Anticline

The Montecito anticline was mapped by Lian (1952) from exposures in the sea cliffs south of the Santa Barbara Cemetery, and was extended offshore to the southeast by Hoyt (1976). As exposed in the sea cliffs, gently dipping Casitas strata are overlain by flat-lying marine terrace deposits, indicating that folding post-dates deposition of the Casitas and pre-dates the marine terrace deposits.

Mesa Fault

The Mesa fault extends southeast from its intersection with the More Ranch fault across the City of Santa Barbara (Plate I). The steep north-facing scarp along the southwest side of the city is inferred to be a resequent fault-line scarp of the Mesa fault. The offshore segment of this fault was mapped by Hoyt (1976) on the basis of seismic profiles, and the fault may continue east to the Carpinteria area as the Rincon Creek fault (Jackson & Yeats, 1982). The Mesa fault follows the axis of the large pre-Santa Barbara structural high discussed previously. Below the alluvial plain, the fault brings the Sespe Formation on the south into fault contact with Santa Barbara-Casita(?) strata on the north. The Sespe Formation crops out immediately south of the inferred fault trace where the strata dip 72° south (Plate I). This may indicate that the Mesa fault follows bedding below the basin unconformity.

The available subsurface data from water well drilling are sufficient to show that north of the Mesa fault, the Santa Barbara-Montecito basin deepens to the southeast (Plate III). Surface outcrops of the basin unconformity south of the Mesa fault do not show a similar southeastward deepening, which suggests a southeastward increase of separation along the Mesa fault, as inferred from the differences in altitude of the basin unconformity across the fault.

Mission Ridge Fault

The Mission Ridge fault trends eastward from the intersection of the More Ranch and Mesa faults (Plate I). The fault cross cuts the pre-basin structural trend immediately east of its intersection with the Mesa and More Ranch faults (Plate III), but in the Mission Ridge area the fault trends parallel to bedding. Water well data, and interpretations of structural contours of the basin unconformity suggest that this fault continues eastward as the Arroyo Parida fault (Plate III). This fault is considered a potentially active, post-basin fault because it deforms Quaternary fanglomerate.

San Jose Fault

The San Jose fault, located northeast of Goleta Valley, is a northwest-trending south-side up fault, which deforms Quaternary fanglomerate and is included in this report as a potentially active, post-basin fault.

SEISMICITY

The record of historical seismicity in the Santa Barbara area is one of the more complete in California, because Santa Barbara is the site of one of the original Spanish missions. Most of the significant earthquakes which affected the area from 1800 to the present are summarized in the Santa Barbara County Seismic Safety Element (1979), and by Olsen and Sylvester (1975).

The earliest reported earthquake felt in Santa Barbara occurred November 11, 1800 and inflicted light damage to the Santa Barbara Mission. The earliest reported major shock occurred December 21, 1812 and destroyed the Royal Presidio, a Spanish fortress, and partially destroyed the Mission. The June 29, 1925 Santa Barbara earthquake (magnitude 6.3) destroyed much of the City of Santa Barbara including the Mission. The earthquake was described by Willis (1925), and a historical review was presented by Olsen and Sylvester (1975). Willis speculated that the earthquake was related to failure along a deep-seated fault plane and that the earthquake energy may have been transmitted and concentrated along subsidiary faults which branch off and reach the surface. According to Willis such a hypothesis may explain why the damage in a given area seemed to be heaviest along existing faults such as the Mesa fault.

In the last 12 years seismographic coverage of the Santa Barbara Channel region has been substantially improved, and includes stations operated by the U.S. Geological Survey, Caltech, University of Southern California, and the University of California at Santa Barbara. As a result, several reports on the seismicity of the Santa Barbara Channel have recently been published. Sylvester (1970) suggested that the 1968 earthquake swarm may be characteristic of seismicity in the Channel. The swarm consisted of 63 earthquakes of which the largest had a magnitude of 5.2. The activity occurred along the offshore extension of the Oak Ridge horst known as the Montalvo trend (Weaver 1969), or the Montalvo anticlinorium (Fischer, 1976). Focal mechanism determinations indicate right oblique-slip movement along a northwest-trending structure, which is inconsistent with the general view that faults in the channel strike east-west and are left-lateral oblique-slip faults. This view is influenced by evidence of left-slip on the Santa Ynez fault north of the channel, and on the Santa Rosa fault south of the channel.

Lee and Vedder (1973) reported on the seismicity in the Santa Barbara channel area from 1970 to 1971. A composite plot of 10 earthquakes in the general vicinity of the 1968 swarm suggests left lateral strike-slip movement along a fault striking N77°E and dipping steeply north. This is consistent with fault orientations and movement directions inferred for several known faults in the region.

Corbett and Johnson (1978, 1982) and Lee et al. (1978) described the M_L 5.1 1978 Santa Barbara earthquake. This earthquake represents the most significant seismic event to occur in the

Santa Barbara metropolitan area in the last 40 years, and, because of the improved seismic network, it is the best documented one. In their study, Lee et al. (1978) located the epicenter approximately 2.5 miles (4 km) south of Santa Barbara, and the hypocenter at a depth of 7.5 miles (12 km). They favored a reverse fault trending N66°W and dipping 40-60° north, but they were unable to correlate the earthquake to a specific fault. Corbett and Johnson (1982), using the same data, but a different velocity model, relocated the epicenter and aftershocks consistently north of the locations of Lee et al. (Figure 7), and estimated a hypocentral depth of 7.9 miles (12.7 km). They also favored a north-dipping reverse fault which trends N80°W and dips 26° north. Both studies revealed a linear aftershock distribution which trends N70°W from the mainshock (Figure 7a). This trend is parallel to that of the Mesa fault which reaches the surface directly over the aftershocks. The locus of seismic activity moved upward and northwestward through time during aftershock activity (Corbett and Johnson, 1982). Corbett and Johnson suggest a model whereby the mainshock and aftershocks occurred along a series of complex, northwest-trending, north-dipping, imbricate thrust faults which flatten into a mid-crustal horizontal shear plane.

The seismic data and local geology do not preclude an origin along the alternative nodal plane which, by Corbett and Johnson's calculations, trends N45°W and dips 68° southwest. This orientation does not rule out a possible origin along the Mission Ridge

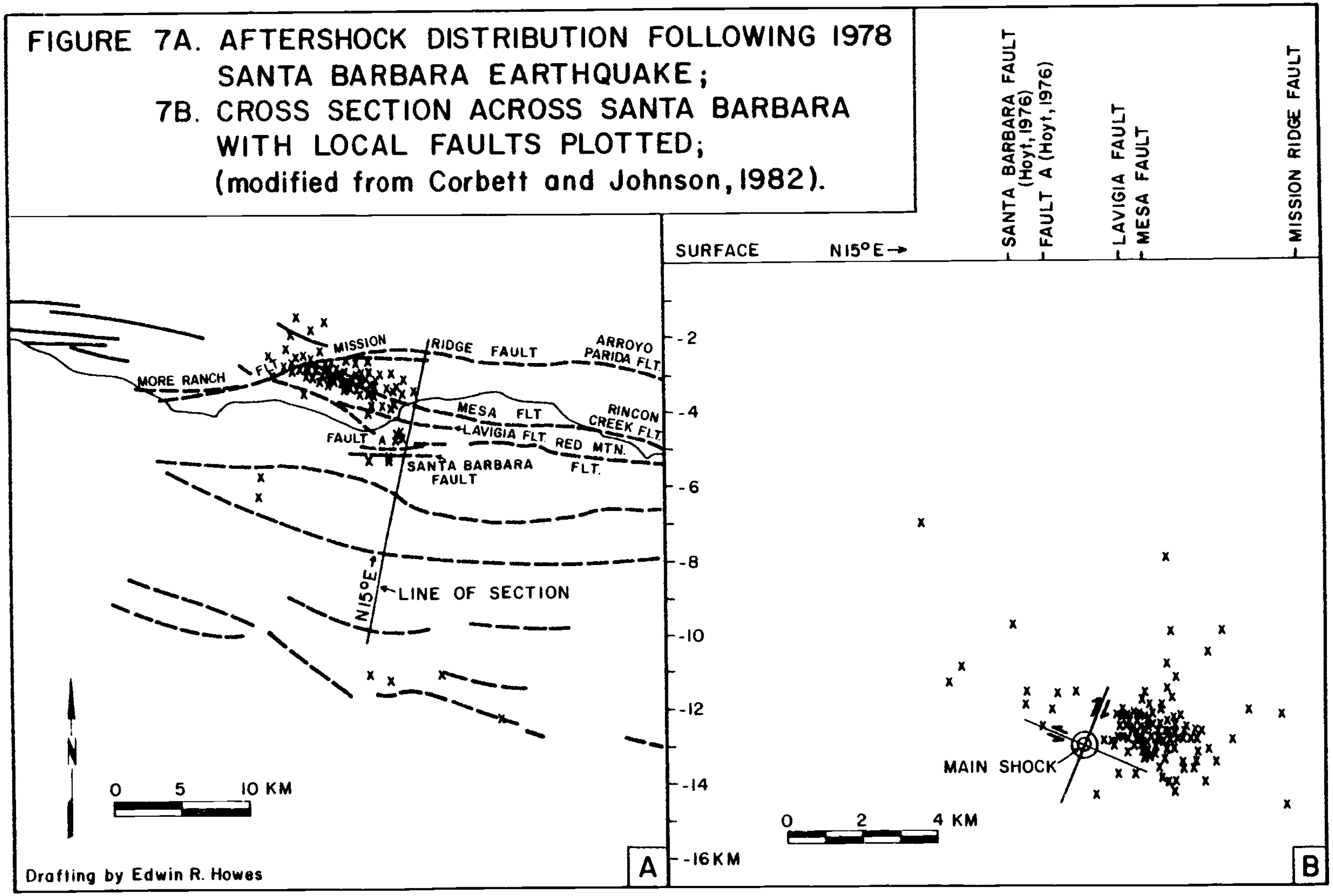


FIGURE 7A. AFTERSHOCK DISTRIBUTION FOLLOWING 1978 SANTA BARBARA EARTHQUAKE;
7B. CROSS SECTION ACROSS SANTA BARBARA WITH LOCAL FAULTS PLOTTED;
(modified from Corbett and Johnson, 1982).

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or Mesa fault because the fault dips at depth are unknown for these faults (Figure 7b). Although the Corbett and Johnson model is intriguing, it does not account for the linear distribution pattern of aftershocks which is more consistent with a high-angle fault. If the earthquake and aftershocks were produced along one of these south-dipping faults, it would indicate that these faults are not of flexural-slip origin, and that they must extend into high strength rocks far below the fold zone along the northern margin of the Santa Barbara Channel.

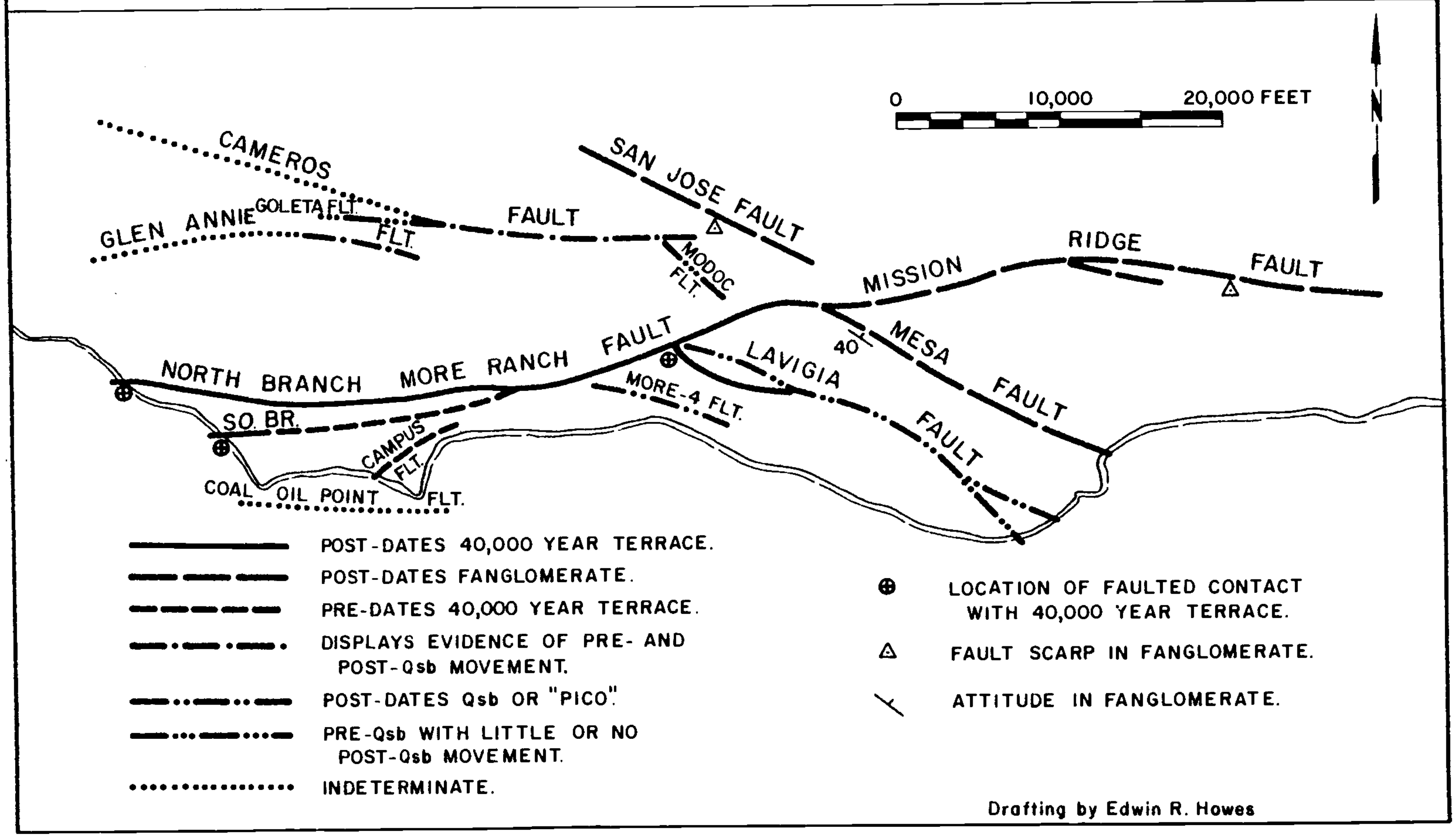
SEISMIC AND GROUND RUPTURE HAZARD

Yeats et al. (1982) recently demonstrated that active faults may be classified on the basis of the type of hazard presented. There are two types of hazards posed by active faults: surface rupture and seismic shaking. An active fault may be capable of one or both of these hazards. Faults which occur along bedding planes and move in response to flexural-slip during folding pose a surface rupture hazard but possibly not a seismic shaking hazard. Faults which extend down to high shear strength rocks pose a seismic-shaking hazard and may or may not pose a surface rupture hazard depending on whether they extend to the surface or not.

None of the faults in the study area cut dated Holocene deposits, therefore, none can be demonstrated as active. However, faults which disrupt late Pleistocene deposits and are considered potentially active include the More Ranch, Mission Ridge, Mesa, Lavigia and San Jose faults (Figure 8).

Subsurface data were not sufficient to determine whether the faults extend downward into bedding or into high strength rocks at depth. As seen on Plate III, the Mission Ridge and More Ranch faults apparently cut across bedding at high angles near their intersections with the Mesa fault. Beyond this area, both faults generally trend parallel to bedding. The trends of the Mesa, Lavigia, and San Jose faults, are parallel or subparallel to bedding strikes and inferred pre-basin structural trends (Plates I

FIGURE 8. RECENCY OF FAULTING IN THE SANTA BARBARA-GOLETA METROPOLITAN AREA.



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and III). Therefore all of the potentially active faults present surface rupture hazards, but any assessments of their seismic shaking potential are speculative. The Coal Oil Point fault cannot be demonstrated as potentially active or inactive, but it is considered to be part of the set of south-dipping, south side up faults. This fault is an example of a fault that does not pose a surface rupture hazard because it fails to reach the surface, but may pose a seismic-shaking hazard if it extends down to high strength rocks and is still active or potentially active.

GEOLOGIC HISTORY

The Paleogene strata of the central Santa Ynez Mountains were deposited in a marine basin which includes the Santa Ynez basin of Nilsen and Clark (1975) and the younger Santa Barbara embayment of Loel and Corey (1932). This basin, a precursor to the Neogene Ventura basin (Yeats, 1978), includes the present day area of the Santa Ynez Mountains, Santa Barbara coastal plain, and Santa Barbara Channel. Near the close of the Eocene, marine deposition of the Coldwater Formation gave way to non-marine deposition of the Sespe Formation as the sea regressed during the emergence of the "San Rafael Uplift" in the area north of the Santa Ynez Mountains (Dibblee, 1966). In the subsurface of the Santa Barbara area, the change from marine to non-marine deposition is recorded by the alternating gray sandstones, red beds, and blue shales of the Coldwater-Sespe transition zone. Although the area was subaerially exposed throughout Sespe deposition, substantial subsidence must have occurred, as indicated by the thick sequence of Oligocene Sespe red beds.

During the late Oligocene, deposition of the shallow marine Vaqueros Formation marked the onset of renewed transgression into the Santa Barbara embayment. During the latest Oligocene (upper Zemorrian), Vaqueros shelf sedimentation abruptly ceased and was succeeded by deposition of the Rincon Formation at lower bathyal depths (Edwards, 1971; Patet, 1972) with little or no neritic or outer shelf transitional sedimentation between them. During this time, the deep, axial part of the Santa Barbara embayment coincided with the present day central Santa Ynez coastal plain.

By the latest early Miocene (upper Saucesian), open marine conditions persisted over much of the region, and deposition of the siliceous and organic shale and mudstone of the Monterey Formation began (Kleinpell, 1938). This change from the hemipelagic Rincon to the chemically derived Monterey sediments represented profound changes in the middle Miocene sea water chemistry that were related to extensive, contemporaneous volcanism (Dibblee, 1966).

The rapid subsidence which resulted in the change from Vaqueros deposition to Rincon-Monterey deposition, along with volcanism throughout the region, and the possible Miocene crustal rotations in the Transverse Ranges proposed by Luyendyk et al. (1980), are generally believed to be related to the impingement of the East Pacific Rise against the North American plate; however, the relations between these phenomena are poorly understood.

The Sisquoc Formation was deposited under open sea conditions that had persisted from Monterey time (Dibblee, 1966). Northward thinning of the Sisquoc Formation in the Summerland offshore anticline (Jackson and Yeats, 1982) and the occurrence of local unconformities near the Sisquoc-Monterey contact (Dibblee, 1966), may be evidence of the initial rise of the Santa Ynez Mountains during deposition of the Sisquoc (Jackson and Yeats, 1982).

In the study area there is no stratigraphic record of the post-Sisquoc, Pliocene to pre-Santa Barbara interval. In the Santa Barbara Channel this interval is represented by "Repetto," "lower Pico," and "middle and upper Pico" strata which respectively contain microfauna of the Repettian, Venturian, and Wheelerian stages of Natland (1953). In the Carpinteria area these strata overstepped older Sisquoc strata during the continued uplift of the Santa Ynez Mountains and coastal plain area (Jackson, 1982). The extent and nature of post-Sisquoc, pre-Santa Barbara deposition in the Santa Barbara-Goleta area is unknown due to erosion or non-deposition of these strata.

Pre-Santa Barbara deformation occurred along the coastal margin concomitant with the major uplift of the Santa Ynez Mountains. In the Carpinteria and Santa Barbara-Montecito basins, deformation was mainly by folding and regional emergence. In the Goleta basin deformation also included faulting along the Cameros, Goleta, and Modoc faults, and possibly along the Coal Oil Point fault within competent strata at depth.

As emergence continued the central Santa Ynez coastal margin was eroded, and the basin unconformity was formed less than 1.2 Ma ago.

Renewed subsidence during the Pleistocene initiated deposition of the Santa Barbara Formation along the coastal margin of the Ventura basin. Folding and uplift which occurred in the area of the La Goleta gas field before the More Ranch fault formed may have counteracted regional basin subsidence, and may have resulted in thinner Santa Barbara strata in that area. This may represent the initial isolation of the Goleta basin.

During the last million years tectonism accelerated in the Transverse Ranges, especially in the central Ventura basin (Yeats, 1978). In the Santa Barbara area, this period of deformation was characterized by large displacement thrust faulting along the south-dipping More Ranch, Mesa, Lavigia, Mission Ridge, San Jose and possibly the Coal Oil Point fault. Faulting was accompanied by disharmonic folding in the incompetent Miocene strata above relatively broad folds in the competent Oligocene and older strata. Quaternary folding occurred along the Elwood, Montecito, Mesa, and More Ranch anticlines and along the More Mesa syncline and in the Goleta basin.

Deposition of the Santa Barbara Formation continued into middle(?) Pleistocene and was in part accompanied by, and in part succeeded by deposition of non-marine Casitas strata in the areas east of Santa Barbara.

During the mid-Pleistocene, another interval of uplift and erosion occurred as the basins filled with detritus eroded from the rising Santa Ynez Mountains.

During the late Pleistocene non-marine deposition of fanglomerate deposits occurred in piedmont fans at the foot of the Santa Ynez Range, followed by deposition of marine terrace deposits in response to subsidence and/or late Pleistocene eustatic sea level changes. The Mission Ridge, Mesa, and San Jose faults disrupt the fanglomerate, and the Lavigia and More Ranch faults are known to post-date the marine terrace deposits. None of the post-basin faults in the area have unequivocally been proven to be active, though all are considered potentially active.

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APPENDIX

Wells Utilized in Study

Key to Abbreviations Used in Appendix

TD	Total Depth
OH	Original Hole
Rd	Redrill
GL	Ground Level
DF	Derrick Floor
RT	Rotary Table
KB	Kelly Bushing

All townships, ranges, and sections are from the San Bernardino Base and Meridian.

Well No.	Location	Well Name	Elevation	TD	Year
1	T4N R27W Sec. 19	Strikland and Tippet - Duncan - 1	602DF	3971	1929
1A		Strikland and Tippet - Duncan - 1A	602DF	5498	1931
2		Aminoil USA - Duncan Ranch - 1	159DF	4283	1929
3	T4N R27W Sec. 20	Channel Oil and Development - Pinkham - 1	248DF	6302	1924
4		Petroleum Exploration - McWilliams - 1	250GL	3921	1927
5		Ameroil Oil Co. Fellowship - 1	350DF	4128	1936
6		M. M. Humphries Edna Mae - 1	350GL	1600	1935
7	T4N R27W Sec. 27	D. A. Hargrave	49DF	3552	1929
8	T4N R27W Sec. 28	Crude Oil Drilling - No. 1	95DF	2015	1934
9		Crude Oil Drilling - No. 2	75DF	2060	1934
10		Interstate Investment - No. 1	70DF	2129	1935
11		Barmesa Oil Co. - Sanches - 1	100DF	2004	1935
12		Mission Oil Co. - Awl - 1	87DF	2115	1935
13		Dralock Oil Co. - Becksted - 1	440DF	1555	1935
14		R. H. McIntosh - Becksted - 1	575DF	1280	1934
15		Beloil Oil Co. - Cal. St. - 1	156DF	2050	1934
16		Scott-McIntosh Pet. Inc. - Caldwell - 1	450DF	2625	1930
17		Fred E. Cole - Cole - 1	200KB	2133	1933
18		Fred E. Cole - Cole - 2	145GL	2119	1934
19		Fred E. Cole - Cole - 3	135DF	2110	1934
20		Fred E. Cole - Cole - 4	110DF	2127	1934
21		Fred E. Cole - Cole - 5	110DF	1997	1934
22		Fred E. Cole - Cole - 6	120DF	1994	1934
23		Fred E. Cole - Cole - 7	103DF	2012	1934
24		Fred E. Cole - Cole - 8	130DF	2016	1934
25		Fred E. Cole - Cole - 10	168DF	2067	1935
26		Fred E. Cole - Cole - 11	110DF	2059	1934
27		M & L Oil Co. - Consolidated - 1	76DF	2280	1935
28		Dyak Exploration - Dyak - 1	185DF	2546	1936
29		Fair Mesa Oil Co. - Gray - 1	116DF	2037	1934
30		Fred E. Cole - Knott - 1	196DF	2170	1933
31		Fred E. Cole - Knott - 2	196DF	4694	1933
32		Anacapa Oil Co. - Low - 1	100DF	2008	1934
33		Anacapa Oil Co. - Low - 2	100DF	2055	1935
34		Anacapa Oil Co. - Low - 3	100DF	2019	1935
35		Anacapa Oil Co. - Low - 4	85DF	2058	1936
36		Anacapa Oil Co. - Low - 5	177DF	2070	1931
37		Trans-Oceanic Oil Co. - Mdivani - 1	150DF	1963	1938
38		Trans-Oceanic Oil Co. - Mdivani - 2	120DF	1540	1939
39	T4N R27W Sec. 2	Trans-Oceanic Oil Co. - Mdivani - 3	92	1529	1939
40		Trans-Oceanic Oil Co. - Mdivani - 4	90	1584	1939

Well No.	Location	Well Name	Elevation	TD	Year
41	TN4 R27W Sec. 27	Trans-Oceanic - Mdivani - 5	85DF	1916	1940
42		Trans-Oceanic - Mdivani - 6	100DF	1548	1940
43		Trans-Oceanic - Mdivani - 7	83DF	2206	1941
44		Trans-Oceanic - Mdivani - 8	52DF	10047	1948
45	T4N R27W Sec. 28	Trans-Oceanic - Mdivani - Wallace 14	150DF	1792	1940
46		Olympic Refining Co. - Mesa - 1	122DF	2520	1929
47		Mid-Western Oil Co. - Midwestern - L - 1	40DF	2054	1937
48		ARCO - Perkins - 1	112DF	1994	1934
49		ARCO - Perkins - 2	82DF	2054	1934
50		ARCO - Perkins - 3	100DF	2005	1934
51		ARCO - Perkins - 4	95DF	2051	1934
52		ARCO - Perkins - 5	93DF	2006	1934
53		ARCO - Perkins - 6	134DF	2094	1934
54		ARCO - Perkins - 7	106DF	2001	1934
55		Kenneth L. Switzer - Rogers - 1	185DF	2119	1930
56		D. A. Hargrave - Low - 2	68DF	1853	1930
57		Pacific Gulf Oil Inc. - Cole - 9	200DF	2100	1932
58	T4N R27W Sec. 29	Altodena Oil Co. - Caldwell - 1	163DF	4270	1929
59		Altadena Oil Co. - Hughes - 1	156DF	1506	1929
60		Union Oil - Durer - 1	175DF	2504	1929
61		Olympic Refining Corp. - Fee - 1	175GL	2020	1930
62		Mobil Oil - Wheeler - 1	183DF	2419	1929
63		Pacific Weter Oil Co. - Pali. - Comm. - 1	182DF	2151	1929
64		Ring Oil Co. - Nugent - 1	154DF	2406	1929
65	T4N R27W Sec. 30	Lincoln Drilling Co. - Medcliffe - 1	10GL	2434	1932
66A	T4N R28W Sec. 2	Getty Oil Co. - Core Hole - 1	226RT	258	1953
66B		Getty Oil Co. - Core Hole - 2	282RT	633	1953
66C		Getty Oil Co. - Core Hole - 3	348RT	427	1953
66D		Getty Oil Co. - Core Hole - 4	358RT	186	1953
67	T4N R28W Sec. 1	Carey and Adams - Montechulo - 1	450GL	2846	1929
68		Marathon Oil Co. - Prevedello - 1	616RT	3266	1946
69	T4N R28W Sec. 2	Southwest Production - Pickett - 1	475GL	3161	1928
70	T4N R28W Sec. 3	Irma Investment - Stevens - 1	250GL	4005	1929
71					
72	T4N R28W Sec. 5	Tesoro Petroleum - Franklin - 1	102KB	2480	1953
73	T4N R28W Sec. 7	Marathon Oil Co. - Bishop - 1	134RT	3241	1947
74	T4N R28W Sec. 6	Marathon Oil Co. - Bishop - 2	153RT	2060	1947
75	T4N R28W Sec. 7	Rothschild Oil Co. - Bishop - 1	208KB	3973	1951
76		Sun Oil Co. - Bishop - 1	75KB	3300	1954
77		Sun Oil Co. - Stowe - 1	101KB	2252	1954
79		Stow Ranch Co. - Core Hole - 1	466L	124	?
80		Stow Ranch Co. - Core Hole - 5	186L	509	

Well No.	Location	Well Name	Elevation	TD	Year
81A		Texaco Inc. - Core Hole - V-4	45'GL	298	
81B		Texaco Inc. - Core Hole - V-9	59'GL	254	
81C		Texaco Inc. - Core Hole - V-10	42GL	300	
81D		Texaco Inc. - Core Hole - V-11	16'GL	440	
81E		Texaco Inc. - Core Hole - V-12	476L	259	
81F		Texaco Inc. - Core Hole - V-12A	60'GL	134	
81G		Texaco Inc. - Core Hole - V-13	276L	190	
81H		Texaco Inc. - Core Hole - V-14	63GL	119	
81I		Texaco Inc. - Core Hole - V-14A	60'GL	82	
81J		Texaco Inc. - Core Hole - V-15	17'GL	405	1952
81K		Texaco Inc. - Core Hole - V-18	576L	184	
81L		Texaco Inc. - Core Hole - V-19	876L	114	
81M		Texaco Inc. - Core Hole - V-20	956L	71	
81N		Texaco Inc. - Core Hole - V-21	74'GL	31	
81O		Texaco Inc. - Core Hole - V-22	776L	60	
81P		Texaco Inc. - Core Hole - V-23	1006L	44	
81Q		Texaco Inc. - Core Hole - V-24	806L	36	
81R	T4N R28W Sec. 8	Texaco Inc. - Core Hole - T1	436L	769	
81S		Texaco Inc. - Core Hole - T2	456L	648	
81T		Texaco Inc. - Core Hole - T3	47GL	491	
82		Elwood Consol. 0116 - Cavalletto - 1	60GL	3430	1927
83	T4N R28W Sec. 9	Hastains-Stine - Simonds-Campbell - 1	55'KB	3714	1934
84	T4N R28W Sec. 10	Nevada Standard Oil Co. - Langman - 1	57'KB	4721	1929
85		North American Oil Consolidated - Pinkham - 1	185GL	2480	1934
86	T4N R28W Sec. 11	Bruer and Curran Oil Co. - Scott-Allstates - 1	153KB	3000	1958
87		Chevron USA - County - 1	153DF	2472	1929
88		Del Mar Oil - Rowe - 1	110'KB	4240	1941
89		Getty Oil - County - 1	170RT	1497	1954
91	T4N R28W Sec. 12	Security Land and Royalty - County - 1	250GL	3290	1942
92	T4N R28W Sec. 15	Mobil Oil Co. - More - 4	96GL	4757	1939
		RD 1		4100	1939
93	T4N R29W Sec. 16	Marathon Oil Co. - Oakley-Bonnette - 1	15GL	6187	1931
94		Ring Petroleum Co. - Marion More - 1	45GL	5570	1930
95	T4N R28W Sec. 17	Chevron USA - Chase and Bryce - 2	55DF	4850	1934
		RD 1		2695	
		RD 2		3521	
		RD 3		3507	
		RD 4		4779	
		RD 5		2250	

Well No.	Location	Well Name	Elevation	TD	Year
96	T4N R28W Sec. 18	Amerada Petroleum - Perry - 1	31KB	3603	1952
97A	T4N R28W Sec. 7	Texaco Inc. - Core Hole - V-5	22GL	79	1946
97B	T4N R28W Sec. 18	Texaco Inc. - Core Hole - V-7	20GL	270	1940
97C		Texaco Inc. - Core Hole - V-16	16GL	480	1940
97D		Texaco Inc. - Core Hole - V-17	26GL	199	1940
98					
99	T4N R28W Sec. 19	Earl Petroleum - Lanter - 1	50DF	5273	1928
100		Getty Oil Co. - Honolulu - Signal-State 309-1	50KB	3962	1947
		Redrill - 1		4404	1947
101		Getty Oil Co. - Honolulu - Signal-Macco-State-309-2	49KB	10054	1947
102		Getty Oil Co. - State 309-3	50KB	10018	1948
103		Aminoil USA - Honolulu-Signal-State 309-4	52KB	10072	1952
		Redrill - 1		9699	1952
104		Petroleum Securities - Storke - 1	37GL	5567	1928
105	T4N R28W Sec. 30	Petroleum Securities - Bishop - 1	47KB	5255	1928
106	T4N R28W Sec. 20	Shell Oil Co.	62KB	6508	1934
107		Chevron USA - Chase and Bryce - 1	12GL	4397	1933
108		Southern California Gas Co. - Miller - 9	27KB	4490	1975
109		Southern California Gas Co. - Miller - 10	27KB	4425	1975
110		Southern California Gas Co. - Miller - 11	27KB	4750	1975
111		Southern California Gas Co. - Miller - 1	27KB	4510	1944
112		Southern California Gas Co. - Miller - 2	25DF	4237	1944
113		Southern California Gas Co. - Miller - 3	27KB	4514	1948
114		Southern California Gas Co. - Miller - 4	27KB	4232	1949
115		Southern California Gas Co. - Miller - 5	13DF	4315	1949
117		Southern California Gas Co. - Miller - 6	25DF	4237	1944
118		Southern California Gas Co. - Miller - 7	62KB	4405	1952
119		Southern California Gas Co. - Edwards - 1	25DF	4288	1951
120		Southern California Gas Co. - Edwards - 2	75KB	4931	1951
121	T4N R28W Sec. 21	Mobil Oil Co. - Crandall 138-1	27KB	4931	1930
122		Mobil Oil Co. - More - 1	76KB	4533	1928
123		Mobil Oil Co. - More - 2	61KB	4343	1929
124		Mobil Oil Co. - More - 3	89KB	6912	1930
126		Southern California Gas Co. - Miller - 8	75KB	4455	1955
127		Southern California Gas Co. - Miller - 12	27KB	4720	1975
128	T4N R28W Sec. 22	Mobil Oil Co. - More - 5	104GL	4905	1939
129	T4N R28W Sec. 30	ARCO Richfield - Honolulu-Signal State 309-5	48KB	6660	1955
		Redrill 1		2885	1955
		Redrill 2		2210	1955
		Redrill 3		6399	1956
		Redrill 4		4631	1956

Well No.	Location	Well Name	Elevation	TD	Year
130	T4N R28W Sec. 12	St. Vincents Orphanage	140GL	308	1943
131	T4N R27W Sec. 20	Veronica Syndicated Veronica Springs 1	50GL	538	1929
132	T4N R29W Sec. 1	W. T. Barnhart Pomatto L	141DF	2154	1927
133		Berry Oil Co. - Cavaletto - 1	164DF	2507	1927
135	T4N R29W Sec. 2	Santa Barbara Oil Co. - Elwood 1	221DF	1630	1927
136	T4N R29W Sec. 3	Sunset Pacific Oil Co. - Doty 1	582DF	2089	1927
137		Crawforld and Hiles Western - Hollister - 1	531KB	1577	1952
138		Cube Oil Co. - Hollister 2A	549DF	1624	1927
139		Daniel Fisher - Hollister-Fisher 1	340GL	1428	1949
140		Cube Oil Co. - Hollister - 8A	540DF	1348	1940
141		Miley Petroleum - Goleta 1	479DF	5664	1926
142		Miley Petroleum - Goleta 1A	483DF	1530	1927
143		Miley Petroleum - Goleta 2	301GL	1330	1927
144		Miley Petroleum - Goleta 4	402DF	1477	1927
145		Miley Petroleum - Goleta 5	385DF	1580	1927
146		Miley Petroleum - Goleta 9	464KB	1478	1927
147		Revo Oil Co. - Revo 1	250GL	1490	1950
148		Cube Oil Co. - Hollister 1A	571DF	1610	1927
149		Cube Oil Co. - Hollister 3A	505DF	1377	1927
150		Cube Oil Co. - Hollister 3A	526DF	1650	1927
151		Cube Oil Co. - Hollister 6A	459DF	1482	1927
152		Cube Oil Co. - Hollister 7A	187DF	1236	1928
153		Yellowstone Oil Co. - Hollister Y-1	340GL	1398	1950
154		Yellowstone Oil Co. - Hollister Y-2	318RT	1315	1950
155		Cube Oil Co. - Hollister - 1	381DF	1317	1932
156	T4N R29W Sec. 4	Miley Petroleum - Goleta - 7	213DF	1441	1927
157	T4N R29W Sec. 4	Miley Petroleum - Goleta - 8	208DF	1221	1927
158		John Baldwin - Baldwin-Dreyfus 1	410KB	2014	1958
159		Miley Petroleum - Goleta - 3	249DF	637	1927
161	T4N R29W Sec. 5	Union Oil Co. - Union-Dreyfus 1	241KB	3052	1954
162		Miley Petroleum - Drefus 1	225DF	2030	1929
164	T4N R29W Sec. 8	Carlton Beal - Dreyfus 2	286GL	4400	1951
165		Shell Oil Co. - Dreyfus 1	273GL	2142	1945
166		Aminoil USA - State 129-8	110KB	4924	1945
168		Aminoil USA - State 129-4A	14GL	5121	1945
169		Aminoil USA - State 129-51	101KB	7988	1947
		Redrill 1		6377	1947
173	T4N R29W Sec. 10	Cal-L Exploration - Hollister 1	316KB	4592	1964
174		Cal-L Exploration - Hollister 2	300GL	7041	1964
175		Joe Ferring - Langlo - 1	140GL	2864	1931
176		Santa Goleta Pet. Co. - Santa Claus 1	310KB	1766	1950

Well No.	Location	Well Name	Elevation	TD	Year
177	T4N R27W Sec. 10	Shell Oil Co. - Hollister 1	280DF	2977	1935
178		Shell Oil Co. - Hollister 2	265GL	3819	1935
179		Cal-L Exploration - Langlo - 1	109KB	3141	1964
180		Cal-L Exploration - Hollister 3	280GL	2919	1964
181		Cal-L Exploration - Hollister 4	310GL	1875	1965
182	T4N R29W Sec. 11	Chevron USA - Eaton 1	117DF	3596	1958
183		Rice and Firestone - N. Elwood - Doty 1	130GL	3327	1947
		Redrill 1		3611	1947
184	T4N R29W Sec. 12	Petroleum Securities - Pomatto A1	112GL	2782	1929
185		Sunset Pacific - Pomatto 1	100GL	484	1931
186		Texaco Inc. - Core Hole - V-1	60GL	110	1940
187	T4N R29W Sec. 13	Fire-Rice Drilling - Harbel-1	102GL	3731	1949
188		L.B. Tannenhill - Storke - 1	10GL	5487	1929
189		Texaco Inc. - Bishop A-1	41DF	4350	1940
190		Texaco Inc. - Bishop A-2	48KB	3025	1941
191		Texaco Inc. - Bishop A-3	38KB	3259	1941
192A		Texaco Inc. - VD Sho Hole 1	49GL	265	1940
192B		Texaco Inc. - Core Hole - V-2	58GL	125	1940
192C		Texaco Inc. - Core Hole - V-3	48GL	186	1940
192D		Texaco Inc. - Core Hole - V-6	63GL	345	1940
192E		Texaco Inc. - Core Hole - V-8	90GL	95	1940
193	T4N R29W Sec. 14	R. S. Rheem - T. B. Bishop - 1	30KB	4537	1955
194		Rice and Firestone - Rice-Firestone 3	124GL	4330	1948
		Redrill 1		3595	1948
		Redrill 2		3625	1948
		Redrill 3		3367	1948
195		Sun Oil Co. - Bishop - Evans 1	51DF	6730	1930
196		Sun Oil Co. - Elwood-Community 1	34DF	5667	1928
197		East Elwood Petroleum - Elwood - 1	85GL	3767	1935
199		Rice and Firestone - Doty Core Hole 1	60GL	205	1948
200		Rinde Oil Co. - Petan 1	27KB	4726	1965
201	T4N R29W Sec. 15	ARCO Elwood Water Disposal 1	31KB	5510	1973
202		Sun Oil Co. - Luton-Bell 10	19DF	3389	1931
203		Sun Oil Co. - Luton-Bell 11	19DF	3612	1930
204		Sun Oil Co. - Luton-Bell 12	19DF	8506	1932
205		Sun Oil Co. - Luton-Bell 14	19DF	4385	1929
206		Sun Oil Co. - Luton-Bell 19	80GL	5690	1938
207		Sun Oil Co. - Permit 88-11	24DF	6391	1941
208		Sun Oil Co. - Permit 88-12	24KB	4297	1941
209		Getty Oil Co. - State 90-9	23KB	7014	1935
210		Sun Oil Co. - Luton-Bell 23	88KB	7945	1969

Well No.	Location	Well Name	Elevation	TD	Year
211		Sun Oil Co. - Luton-Bell 21-15	83KB	5208	1961
212		Sun Oil Co. - Luton-Bell 22	84KB	3375	1963
213		Aminoi Archambeault - Doty 1	150KB	4584	1929
214	T4N R29W Sec. 16	Aminoil - State 129	?	4750	1944
217		Getty Oil Co. - Blue Goose 93-12	22KB	4400	1954
224	T4N R29W Sec. 23	International Oil Co. - Bishop Ranch 1	18KB	4643	1964
225		J. E. O'Donnell - Campbell 1	45DF	5515	1929
226		Cady Oil - Bishop 1	40GL	5955	1928
227	T4N R29W Sec. 14	Equity Oil and Royalty - Permit 159-1	25KB	3785	1930
228		Getty Oil Co. - Honolulu-Signal-Goleta-Community 1	45DF	6747	1947
229		Getty Oil Co. - Honolulu-Signal-Macco-State 308-1	44KB	4161	1948
		Redrill		4934	1948
230		Union Oil Co. - Campbell Ranch 1	25DF	5076	1946
231		Union Oil Co. - Storke 1	25DF	5022	1945
233A		Texaco Inc. - Bishop Core Hole 1	33GL	1483	1930
233B		Texaco Inc. - Bishop Core Hole 2	17GL	744	1930
234A	T4N R29W Sec. 25	Bolsa Chica Oil Co. - Auger 1	27KB	5510	1930
234B		Bankline Oil Co. - 191-2	27KB	4187	
234C		Bolsa Chica Oil Co. - 191-7	27KB	4314	?
234D		South Basin Crude Oil Co. - 191-2	27KB	4020	?
235		Doyle Petroleum Co. - 191-3	27KB	4163	1935

Water Wells

		Index Number	Elevation	TD
T4N	R26W			
	Sec. 7	R1	275GL	952
	Sec. 8	P1	180GL	550
	Sec. 8	G1	340GL	590
	Sec. 17	G1	100GL	390
	Sec. 17	K1	85GL	1150
	Sec. 17	N1	85GL	700
	Sec. 18	B1	245GL	395
	Sec. 18	H1	160GL	175
T4N	R27W			
	Sec. 7	H3	270GL	540
	Sec. 8	E1	240GL	600
	Sec. 8	L2	225GL	615
	Sec. 8	J1	240GL	655
	Sec. 13	R1	35GL	545
	Sec. 14	P1	30GL	?
	Sec. 14	Q1	30GL	730
	Sec. 15	J1	25GL	725
	Sec. 15	Q9	30GL	720
	Sec. 16	E1	130GL	700
	Sec. 17	Smarkland Hotel	190GL	585
	Sec. 24	D2	15GL	605
T4N	R28W			
	Sec. 3	M7	120GL	335
	Sec. 4	R2	90GL	500
	Sec. 8	P4	20GL	1070
	Sec. 9	A2	86GL	340
	Sec. 9	M1	31GL	329
	Sec. 12	K2	130GL	390
	Sec. 12	L4	160GL	310
	Sec. 16	R1	30GL	610