AN ABSTRACT OF THE THESIS OF

DAVID WAYNE HANSON for the degree of MASTER OF SCIENCE

in GEOLOGY presented on June 1, 1981

Title: SURFACE AND SUBSURFACE GEOLOGY OF THE SIMI VALLEY AREA, VENTURA COUNTY, CALIFORNIA

Abstract approved: Redacted for Privacy
Dr. Robert S. Yeats

Surface and subsurface mapping are combined to determine the structure and geologic history of the eastern half of the Simi fault in the Simi Valley area. Upper Cretaceous rocks exposed south and east of the Simi Valley are overlain unconformably by the nonmarine Simi Conglomerate of Paleocene age. The Marine Paleocene unit conformably overlies and is locally interbedded with the Simi Conglomerate; it is composed of Simi Conglomerate clasts that were reworked during a marine transgression. Siltstone of the Santa Susana Formation conformably overlies the Marine Paleocene unit, disconformably overlies the Simi Conglomerate, and was deposited in a deepening marine basin. The overlying Llajas Formation was deposited during a marine regressive-transgressive-regressive cycle. The latter regression continued in late Eocene time with deposition of the overlying nonmarine Sespe Formation.

Extension and normal faulting followed deposition of the Sespe, with the early Miocene Vaqueros Formation being deposited unconformably over the Sespe. Formation

of the Simi anticline and Simi fault occurred after deposition of the Vaqueros and prior to the deposition of the Conejo Volcanics, and resulted in 3850 feet (1173 m) of separation along the Simi fault in the western part of the study area. The Conejo Volcanics were erupted into a structurally controlled marine basin in the Santa Monica Mountains-Conejo Hills area during the middle Miocene. The flows extended northward over the Simi fault to the southwest flank of Big Mountain. Sedimentary rocks of the Topanga Formation were deposited prior to, during, and after deposition of the Conejo Volcanics.

The Neogene Topanga, Modelo, and Pico Formations in the Simi Valley area are thin, discontinuous, and bounded by unconformities, with the late Miocene to early Pliocene Towsley Formation being entirely absent. This implies that the Neogene in the Simi Valley area was characterized by shallow-water sedimentation interrupted by periods of nondeposition and erosion, and is in contrast to the conformable, predominately deep-water Neogene sequence present in the East Ventura basin. The Neogene sequence contains evidence that the Simi Valley became a structural high during the early Miocene and remained elevated through the Pliocene.

Formation of the south-dipping Marr, Brugher, Llajas, Ybarra Canyon, and possibly the Corredo faults is assumed to have occurred during Pico deposition, coincident with the formation of the south-dipping Frew fault in the Aliso Canyon area. Movement along the present trace of the Simi fault truncated the Marr fault and is assumed to have occurred subsequent to Pico deposition. The north-dipping C.D.L.B., Strathearn, and Joughin faults are inferred to have formed at this time, and ceased movement prior to the deposition of the Saugus Formation. Folding of the Happy Camp syncline occurred after deposition of the Saugus, possibly in response to the same northeast-southwest-oriented stressfield that formed the Santa Susana fault.

The Simi fault cuts older alluvium east of Tapo Canyon, but does not cut slump blocks of Conejo Volcanic that overlie the fault north of Tierra Rejada Valley.

Surface and Subsurface Geology of the Simi Valley Area, Ventura County, California

by

David Wayne Hanson

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 1, 1981

Commencement June 1982

APPROVED:

Redacted for Privacy

Professor of Geology and Geology Department Chairman
in charge of major

Redacted for Privacy

Dean of Graduate School

Date thesis is presented June 1, 1981

Typed by Opal Grossnicklaus for David Wayne Hanson

ACKNOWLEDGEMENTS

My appreciation goes to Dr. Robert Yeats for introducing me to the thesis project and for his patience and advice throughout its completion. Thanks go to Dr. Robert Lawrence for reading the manuscript, and to a fellow Texan, Dr. E. Julius Dasch, for serving as a last minute replacement on my thesis committee.

I am indebted to Robert Diem of Texaco for providing summer support, Jane Robles of the California Division of Oil and Gas for her continued cooperation, William Wadsworth of Whittier College for the loan of aerial photographs of the thesis area, Mike Kuhn of the City of Simi Valley for his cooperation, and Donna Batch for her unparalleled drafting expertise.

Special thanks go to my parents and two sisters for their continual support and aid. Finally, I would like to express my dearest appreciation to my colleagues and comrades in the Geology Department who made the past three years in Oregon extremely rewarding and entertaining.

Funding for this study was provided by the United States Geological Survey.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

SURFACE AND SUBSURFACE GEOLOGY OF THE SIMI VALLEY AREA, VENTURA COUNTY, CALIFORNIA

INTRODUCTION

Regional Setting

The Simi Valley area is located in southeastern Ventura and western Los Angeles Counties, about 32 miles (51 km) northwest of downtown Los Angeles and 30 miles (48 km) east of the city of Ventura. The study area covers approximately 78 square miles and is located within the Simi, Santa Susana, and Oat Mountain 7.5 minute quadrangles. It is bounded on the north by Big Mountain and the Santa Susana Mountains, on the east by the San Fernando Valley, on the south by the Simi Hills, and on the west by the Las Posas Hills. The Simi Valley area is a part of the central Ventura basin, which is itself part of the central Transverse Ranges (Figure 1).

The major structural feature in the study area is the Simi fault, which trends west-southwest for about 20 miles (32 km) along the northern margin of the Simi Valley and through the Las Posas Hills. Jakes (1979) described the Springville fault zone in the Camarillo Hills as a westward continuation of the Simi fault. The relationship of the study area to the major geographic and structural features in the central Transverse Ranges is shown in Figure 1.

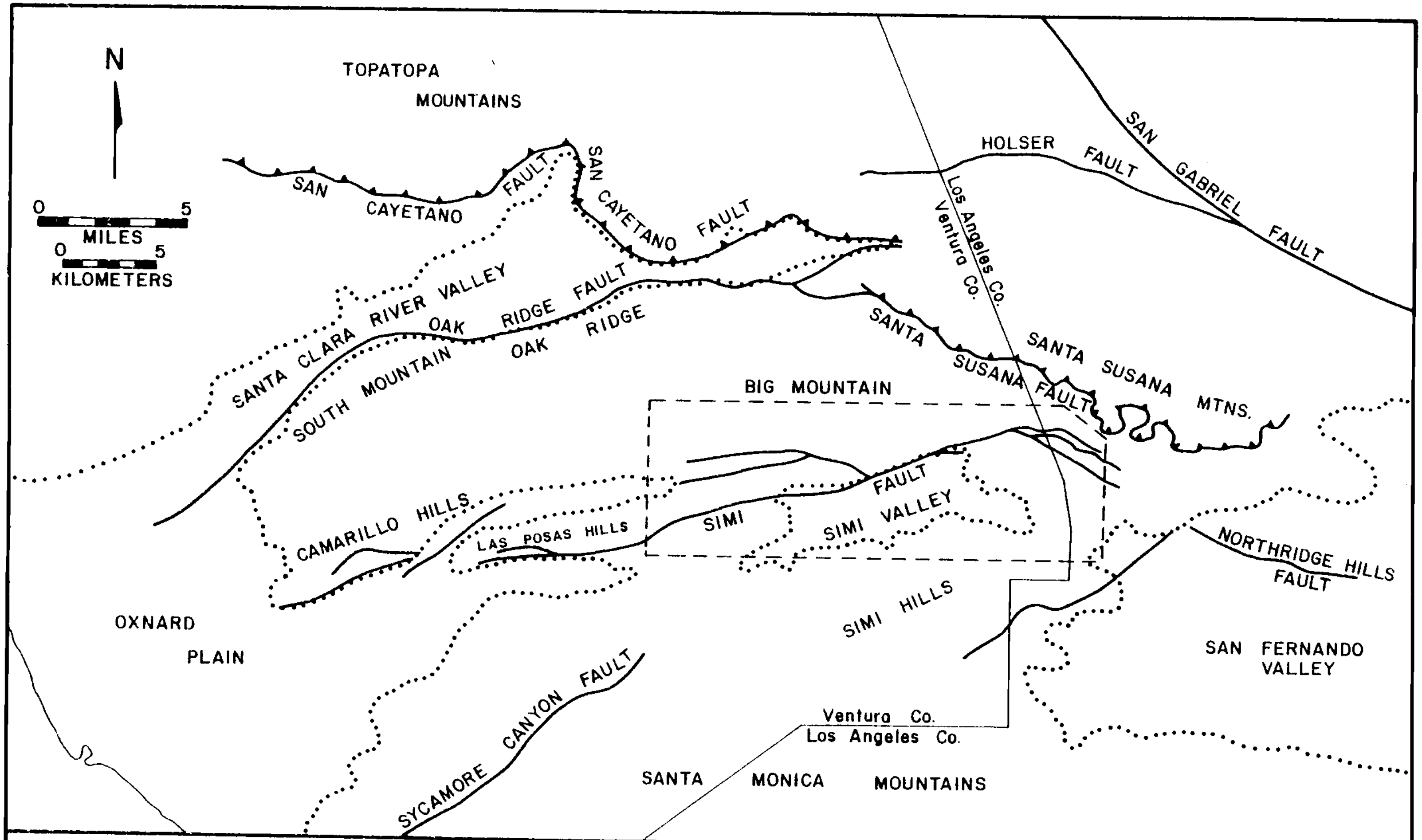

Figure 1—Tectonic map of central Transverse Ranges.
Study area within dashed boundary (after Jennings and Strand, 1969).

The Simi Valley area is part of a Neogene structural shelf that extends north to the Oak Ridge fault. Neogene strata on this shelf are thin and discontinuous, and unconformably overlie Paleogene and Cretaceous rocks. This is in contrast to the thick, continuous Neogene section that exists in the Ventura basin north of the Oak Ridge fault. The Simi fault cuts the Pleistocene Saugus Formation but the remaining post-Miocene faults exposed in the Simi Valley area are pre-Pleistocene in age. In general, the south-dipping reverse faults predate the north-dipping reverse faults.

Purpose of Study

The major purpose of this study is to determine the age and movement history of the Simi fault in the Simi Valley area. The rapid urbanization of the study area makes it necessary to determine the age of most recent movement on the fault, and from this, to ascertain the possible seismic or ground-rupture hazards to the surrounding community. The study on the western part of the Simi fault by Jakes (1979) serves as a starting point for this study. In addition, previous studies from the surrounding areas (see Previous Work section) are used in formulating a geologic history of the Simi Valley area.

Methods of Study

A geologic map of the Simi Valley area was constructed using unpublished masters and Ph.D. theses, engineering geology reports, and private consultant reports. This compilation was field-checked during the summer of 1979 using air photos borrowed from the Fairchild Collection at Whittier College. Corrections and revision of the compiled geologic map were made on the basis of this field work and air photo interpretation.

Electric logs, directional surveys, and core and sidewall descriptions of the 220 oil wells drilled in the study were obtained from the California Division of Oil and Gas (DOG). Additional data, such as dipmeter results and paleontological reports, were obtained from oil companies and private operators in the area. Engineering geology reports covering the study area were obtained from the City of Simi Valley.

Cross sections and contour maps were constructed using the oil well data in the study area. Plate II shows the surface locations of all wells in the study area, along with cross-section locations.

Previous Work

Early regional studies which cover all or part of the Simi Valley area include reports by Hershey (1902),

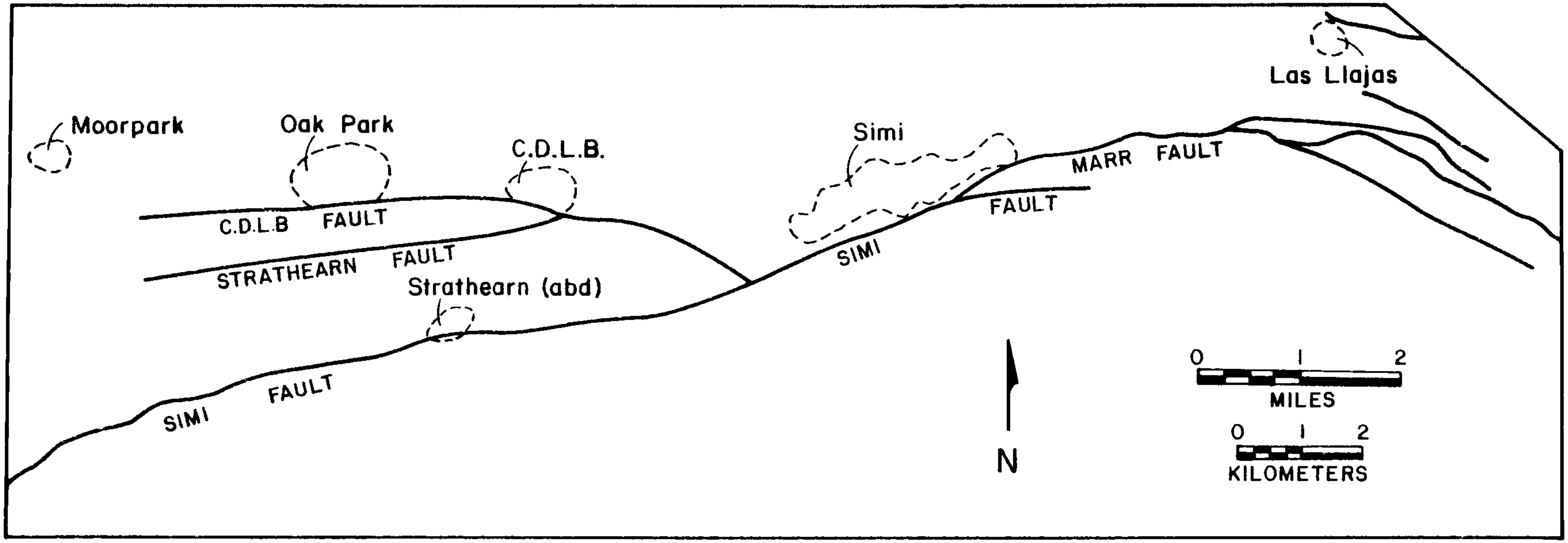

Figure 2 — Oil fields in the Simi Valley area (outlined by dashed lines)
abd = abandoned

Kew (1924), and Taliaferro (1924). Kew (1919) and Stipp (1943) discussed the geology and oil resources of the Simi Valley area.

Some of the earliest published reports on the stratigraphy of the Simi Valley area concerned the biostratigraphy of the Cretaceous and lower Tertiary section exposed in the area. These reports include: Waring (1917), Clark (1918), Nelson (1925), Schenck (1931), McMasters (1933), Clark and Vokes (1936), Cushman and McMasters (1936), Merriam and Turner (1937), Laiming (1939), Merriam (1941), Mallory (1959), Almgren (1973), Popenoe (1973), Poore (1976, 1980), and Squires (1977, 1979). Unpublished masters and Ph.D. biostratigraphic theses were written by Browning (1952), Grier (1953), Schmidt (1971), and Zinsmeister (1974). Stock (1932), Wilson (1949), Savage and Downs (1954), and Durham and others (1954) described vertebrate fossils found in the Sespe Formation, whereas Cushman and Leroy (1936) discussed the age of the Vaqueros Formation, as based on microfauna.

Stratigraphic studies on formations exposed in the Simi Valley area have been done by: Sage (1971) and Colburn (1973) on the Cretaceous rocks, Sage (1973) on the Paleocene section, Bailey (1947) and McCracken (1972) on the Sespe Formation, Edwards (1971) on the Vaqueros Formation, Howell (1974) on the middle Eocene, Williams

(1977) on the Conejo Volcanics, Yerkes and Campbell (1979) on the Conejo Volcanics and the Topanga Formation, Suzuki (1952) on the Topanga Formation, and Pressler (1929) on the Pico and Saugus Formations.

Unpublished masters theses done on parts of the Simi Valley and surrounding areas include those by: Cabeen (1939), Lewis (1940), Levorsen (1947), Hetherington (1957), Bishop (1950), Van Camp (1959), Nett (1973), Canter (1974), Ricketts and Whaley (1975), Lant (1977), Shields (1977), and Jakes (1979). Most of these theses were consulted during compilation of the geologic map. Additional map sources were the U.S. Dept. of the Interior, Bureau of Reclamation, Calleguas Project (1957), Leighton and Associates (1972), Seismic Hazards Study of Ventura County, California, California Division of Mines and Geology (1975), Envicom Corporation (1976), Evans and Miller (1978), and Gorian and Associates (1978).

Topical studies involving the Simi Valley area include Yeats, Butler, and Schlueter (1977) and Yeats (1979) on the Santa Susana fault zone, Turner and Campbell (1979) on the age of the Conejo Volcanics, Kamerling and Luyendyk (1979) on the clockwise rotation of middle Miocene volcanic rocks in the Santa Monica Mouintains, Luyendyk, Kamerling, and Terres (1980) on a geometric model for the Neogene crustal rotations of southern California, and Truex (1976) on the westward translation of the Santa Monica Mountains.

STRATIGRAPHY

Introduction

The stratigraphy of the Simi Valley area encompasses a time interval from Late Cretaceous to the present. The Paleogene strata represent a period of nearly continuous deposition beginning with the continental deposits of the Simi Conglomerate. This is overlain by the transgressive-regressive marine sequence of the Santa Susana and Llajas Formations, and the nonmarine Sespe Formation.

Neogene strata in the Simi Valley area are thin, discontinuous, and bounded by unconformities, with the late Miocene to early Pliocene Towsley Formation being absent. This implies that the Neogene was a period of shallow-water sedimentation interrupted by periods of nondeposition and erosion. This is in contrast to the conformable, predominately deep-water Neogene strata present in the East Ventura basin, north of the present day Santa Susana fault. The Neogene strata indicate that the Simi Valley area became a structural high during the early Miocene and remained elevated through the time of deposition of the Saugus Formation.

Cretaceous

The Cretaceous rocks exposed in the Simi Valley area were described by Waring (1917) as the Chico beds and by Kew (1924) as the Chico Formation. Subsequent workers in the area also used the name Chico Formation. Sage (1971) pointed out that the Cretaceous rocks in the Simi Valley area are lithologically dissimilar from, and are not continuous with the type Chico in northern California. Therefore, the term "Chico Formation" is inappropriate for Cretaceous rocks in the Simi Valley, and is not used in this report. These rocks are referred to as "Upper Cretaceous undifferentiated".

Upper Cretaceous rocks crop out extensively south and east of the Simi Valley. The contact with the overlying Simi Conglomerate is an angular unconformity, with the difference in attitude of the beds never more than a few degrees. Channeling is common along this contact (Sage, 1971).

In the subsurface, the Upper Cretaceous sequence is overlain unconformably by the Santa Susana conglomerate in the Union Las Llajas 9 (#81) well (Cross Section L-L'; Plate XVI). This relationship is also present to the northeast in the Aliso Canyon area, where Lant (1977) noted an angular unconformity between the Upper Cretaceous strata and an overlying conglomerate that he referred to as the Simi Conglomerate. Plate VI demonstrates that this conglomerate (present in the Union Frew 1 well) is actually the Santa Susana conglomerate. In the northwest San Fernando Valley, Shields (1977) reported that an angular unconformity on top of the Cretaceous cuts out progressively older Cretaceous strata eastward.

Southeast of the Simi Valley, an Upper Cretaceous section 6080 feet (1853 m) thick was measured by Sage (1971). He divided this section into a lower, fossiliferous, brown sandstone and mudstone member, a middle, sparsely fossiliferous, light brown, highly resistant sandstone and mudstone member, and an upper, sparsely fossiliferous, weakly resistant, brown sandstone and mudstone member. Interbeds of pebble- to cobble-conglomerate are common throughout the section.

In the subsurface, the Upper Cretaceous sequence is dominated by a light gray, fine- to medium-grained sandstone with abundant mica and kaolinite, and occasional interbeds of mudstone. The sequence is distinguished from the overlying Paleocene on the basis of electric log characteristics: the Simi Conglomerate and the Santa Susana conglomerate have a high resistivity and low spontaneous potential, whereas the Upper Cretaceous strata have a regular alternation of high and low resistivity and spontaneous potential.

Electric log characteristics and ditch sample descriptions indicate that the Marr Ranch 26 and 27 (#106, #87) wells passed through the Simi Conglomerate and bottomed in the Upper Cretaceous (Figure 3; Cross Section J-J', Plate XV). This is contrary to paleontological evidence that implies that both wells bottomed in Paleocene strata. It should be noted, however, that the fossil content of the interval in question in both wells is meager. Because only ditch cuttings from wells were analyzed for fossils, contamination from cavings in the wells could explain the Paleocene age determinations for rocks correlated by electric log with the Upper Cretaceous strata. For these reasons, the Marr Ranch 26 and 27 (#106, #87) wells are interpreted to have bottomed in the Upper Cretaceous.

The Upper Cretaceous strata were interpreted by Colburn (1973) to have been deposited in a relatively deep continental shelf basin by north- and west-flowing turbidity currents. The textural and mineralogical immaturity of the sandstones indicates that the turbidites were proximal (Sage, 1971). Carey and Colburn (1978) believed that the sediments were derived from a volcanic and metasedimentary terrane, possibly the Peninsular Ranges of southern California.

Cretaceous fossils found in the Simi Valley area are mollusks of middle Campanian to early Maestrichtian age (Popenoe, 1973).

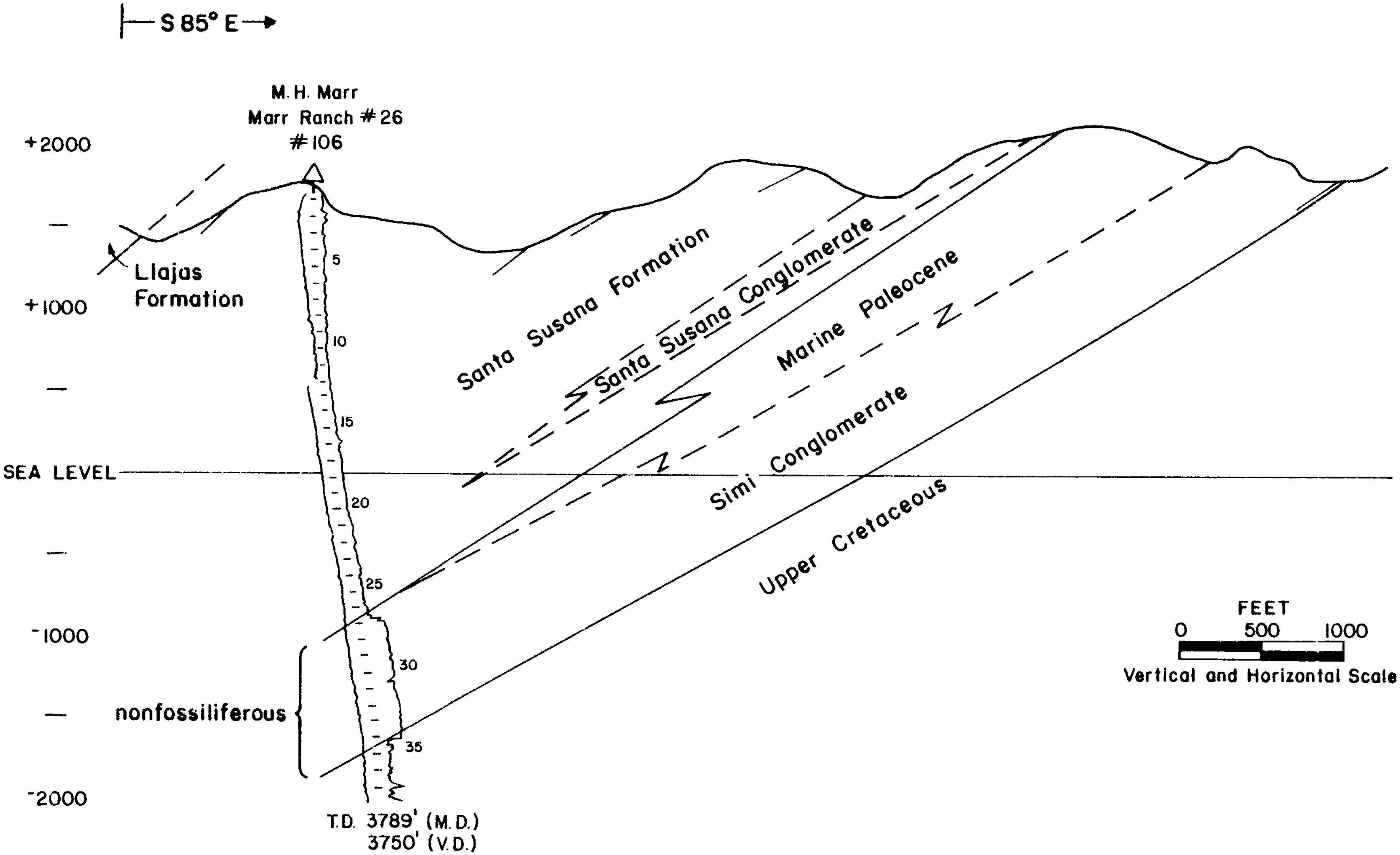

Figure 3—Cross section showing Paleocene facies relationships

Unnamed Paleocene Strata

The lower Tertiary strata of the Simi Valley were mapped and described by Waring (1917). Based upon fossils, Waring divided the section into a lower "Martinez" unit and an upper "Tejon" unit. Kew (1919, 1924) referred to Waring's lower unit as the Martinez Formation. Nelson (1925) further divided Waring's "Martinez" unit into the Simi Conglomerate and the Las Virgenes Sandstone.

The term "Martinez" has been used as a group and as a stage name. Its use as a formational name is based on the occurrence of a certain assemblage of Paleocene fossils and not on a lithologic similarity to a type locality. Its usage as a lithologic unit, therefore, has no basis.

Fantozzi (1955) proposed the name Calabasas Formation for the Paleocene strata in the Simi Valley area. Sage (1973) divided the Calabasas Formation into three members: the Simi Conglomerate, Las Virgenes Sandstone, and the Burro Sandstone, but he incorrectly mapped the Santa Susana Formation on the south side of the Simi Valley as the Burro Sandstone. The name "Calabasas" has since been used by the U.S. Geological Survey as a formational name for middle Miocene strata overlying the Conejo Volcanics in the Santa Monica Mountains (Yerkes and Campbell, 1979). Therefore, the name "Calabasas" is abandoned in this report, and the name Simi Conglomerate is used to describe the nonmarine sandstone and conglomerate directly overlying the Upper Cretaceous sequence. The marine sandstone and conglomeratic sandstone overlying and interfingering with the Simi Conglomerate is referred to informally as the Marine Paleocene unit.

In outcrop, the contact between the Simi Conglomerate and the underlying Upper Cretaceous sequence is a slight angular unconformity. In the subsurface, the reduced thickness of Simi Conglomerate in the Marr Ranch 27 (#87) well, as compared to the Pacific Western Marr 1 (#179) and the Union Simi 24 (#86) wells, implies the existence of irregular, pre-Paleocene topography eroded into the Upper Cretaceous (Plate VI). Similar irregularities in the Simi Conglomerate-Upper Cretaceous contact are evident in outcrop at the head of Poison Oak Canyon and in the vicinity of Santa Susana Knolls (Plate I).

The Simi Conglomerate consists of a lower, nonmarine conglomerate with interbeds of sandstone, and an upper, tan to white arkosic sandstone and olive-gray siltstone. Conglomerate clasts range in size from cobbles to boulders and are composed of volcanic, granitic, and quartzitic rocks. The conglomerate beds are discontinuous and are as thick as 200 feet (61 m); sandstone interbeds are as thick as 6 feet (2 m), with the upper arkosic sandstone and olive-gray siltstone as thick as 70 feet (21 m).

The Marine Paleocene unit is a brown, medium-grained, fossiliferous sandstone and conglomeratic sandstone that is locally interbedded with the Simi Conglomerate west of Santa Susana Knolls on the south side of the Simi Valley. Sage (1973) called this sandstone the Las Virgenes Sandstone. Zinsmeister (1974) stated that the Las Virgenes Sandstone is not present east of the Runkle Canyon fault, and that this fossiliferous sandstone is a marine facies of the Simi Conglomerate. The Marine Paleocene unit pinches out to the southwest such that the Santa Susana Formation directly overlies the Simi Conglomerate in and west of Meier Canyon. The Marine Paleocene unit may be equivalent to the Las Virgenes Sandstone, but it is not called Las Virgenes in this report because it is not laterally continuous with the type Las Virgenes Sandstone west of the Runkle Canyon fault.

The thickness of the Paleocene strata in the study area varies from 1400 feet (427 m) along Meier Canyon to 1200 feet (366 m) along Poison Oak Canyon. North of the Corredo fault, only the Simi Conglomerate is exposed, except for two small lenses of the Marine Paleocene unit.

In the study area, the only correlation possible between a surface exposure of the Paleocene strata and subsurface data is illustrated in Figure 3. The Marr Ranch 26 (#106) well encountered 2670 feet (814 m) of Santa Susana

Formation that is underlain by 700 feet (213 m) of non-fossiliferous Simi Conglomerate. This indicates that the 650 feet (198 m) of Marine Paleocene conglomeratic sandstone exposed at the surface pinches out beneath the Santa Susana Formation, a relationship similar to that observed at the head of Meier Canyon on the south side of the Simi Valley.

In the subsurface, it is not possible to distinguish between the Marine Paleocene unit and the Simi Conglomerate on the basis of electric log characteristics or lithologic descriptions since both units are conglomeratic. The only distinguishing characteristic between the two units is the presence of marine fossils in the Marine Paleocene unit, a characteristic that is difficult to determine due to the often incomplete sampling of the wells. For this reason, the Paleocene conglomerate underlying the Santa Susana Formation in the subsurface is referred to as "Marine Paleocene-Simi Conglomerate undifferentiated". The Paleocene conglomerate in the Marr Ranch 26 (#106) well (Figure 3; Cross Sections J-J', L-L', Plates XV, XVI), however, is referred to as the Simi Conglomerate because the entire conglomerate is nonfossiliferous.

The northernmost and easternmost occurrence of the Marine Paleocene-Simi Conglomerate unit in the subsurface is in the Union Simi 24 (#86) well. To the northeast, in the Union Simi 4 (#76) and Union Las Llajas 9 (#81) wells, the Santa Susana conglomerate rests unconformably on Upper Cretaceous strata, the Marine Paleocene-Simi Conglomerate unit having pinched out toward the northeast (Cross Section L-L', Plate XVI). An eastward pinch out of the Simi Conglomerate is indicated east of the study area, where Shields (1977) reported that the Simi Conglomerate crops out near the Chatsworth Reservoir but is not present in the Atlantic Richfield Pertusati 1 well, 1½ miles (4 km) to the east. In that well, the Santa Susana Formation overlies the Upper Cretaceous strata with angular conformity (Shields, 1977).

The Simi Conglomerate is inferred by Sage (1973) and Zinsmeister (1974) to have been deposited by a southwest-flowing braided river and alluvial fan system. The large clast size and wedge shape of the formation indicate a moderately high relief source area to the east. The Marine Paleocene unit is interpreted by Zinsmeister (1974) to be a near-shore or beach deposit composed of Simi Conglomerate clasts reworked by the transgressing Santa Susana sea.

Browning (1952) noted the presence of two "Martinez" Stage megafossils from the Marine Paleocene unit exposed along Poison Oak Canyon. Mallory (1959) stated that the Simi Conglomerate in the Simi Valley area can be correlated with the Ynezian Stage on the basis of megafossil and microfossil evidence.

Santa Susana Formation

Nelson (1925) divided the lower Tertiary section exposed on the south side of the Simi Valley into four formations: The Simi Conglomerate, Las Virgenes Sandstone, Martinez Marine Member, and the Santa Susana Shale. He considered the Martinez Marine Member to be a distinct lithologic unit underlying the Santa Susana Formation. Mapping by Zinsmeister (1974) showed that the concretionary sandstones of Nelson's Martinez Marine Member are actually sandstone tongues interbedded with siltstone of the Santa Susana Formation. As a result, Zinsmeister (1974) considered Nelson's Martinez Marine Member to be a coarse-grained facies of the Santa Susana Formation.

Browning (1952) considered the base of the Santa Susana Formation to be defined by the Santa Susana conglomerate. In comparing the two lower Tertiary sequences exposed on either side of the Simi Valley, Browning incorrectly correlated the Santa Susana conglomerate on the north side of the valley with the Llajas conglomerate on the south side of the valley. The fact that the Santa Susana conglomerate pinches out west of White Oaks Park and is not present on the south side of the valley led Zinsmeister (1974) to conclude that the "conglomerate represents a temporary regressive facies in the Santa Susana Formation and cannot be used to mark the lower contact of the formation".

In the Meier Canyon area, the contact between the Santa Susana Formation and the underlying Simi Conglomerate is irregular, suggesting a disconformity (Zinsmeister, 1974). Browning (1952) noted that the contact with the Marine Paleocene unit in Poison Oak Canyon is conformable. Cross section L-L' (Plate XVI) and Plate VI indicate that the Santa Susana Formation overlies the Upper Cretaceous strata in the Las Llajas and Aliso Canyon oil fields with angular unconformity, a relationship that also occurs in the northwest San Fernando Valley area (Shields, 1977).

The Santa Susana Formation varies in thickness from 2800 feet (853 m) southwest of Meier Canyon to 875 feet (267 m) along the Arroyo Simi. On the north side of the valley, the formation is 2750 feet (838 m) thick along Las Llajas and Poison Oak Canyons. In the eastern part of the study area, the Santa Susana Formation is bounded on the north by the Llajas reverse fault and on the south by the Ybarra Canyon reverse fault. Its thickness here is not known due to the faulting.

The Santa Susana Formation consists of a sequence of massive, blue-gray siltstone beds that are sandier toward the top of the formation. Lenticular beds of dark grey limestone are common throughout the upper part of the formation. Zinsmeister (1974) recognized three sandstone tongues interbedded with the siltstones on the south side of the Simi Valley. In ascending order, they are the Meier Canyon Tongue, the Burro Flats Tongue, and the Runkle Canyon Tongue. The Meier Canyon Tongue is exposed along the west side of Meier Canyon and consists of light brown, concretionary sandstone with abundant mollusks; it thins abruptly to the east and lenses out east of Meier Canyon. The Burro Flats Tongue is also composed of light brown, concretionary sandstone with abundant mollusks; it pinches out east of Runkle Reservoir and is exposed only south of the study area. The Runkle Canyon Tongue is a light brown concretionary sandstone that is finer grained than the lower two tongues; it pinches out beneath the alluvium of Meier Canyon. The only subsurface correlation of these sandstone tongues with the outcrop is illustrated in Cross Section E-E' (Plate XI), where the sands in the bottom of the Regent Runkle 1 (#54) well may be correlated with the Runkle Canyon Tongue, or the tongue may pinch out before reaching the well.

The Santa Susana conglomerate is a pebble conglomerate consisting of chert, granite, and quartzite clasts with a poorly sorted sandstone matrix. It is 75 feet (23 m) thick at its exposure in Poison Oak Canyon, where its contact with the underlying siltstone is an erosional unconformity. Browning (1952) noted that this unconformity is only locally present. The lenticular nature of the conglomerate is evident from the fact that it is not present on the south side of the Simi Valley and in the Marr Ranch 26 (#106) well (Figure 3; Cross Section J-J', Plate XV). North of the Marr fault, the Santa Susana conglomerate is present in all wells that drilled through the formation.

In the subsurface, the thickness of the Santa Susana Formation varies depending on the amount of deformation that it has undergone. On the north side of the Marr fault, the thickness ranges from 1700 to about 2200 feet (518 to 671 m) in Cross Section H-H' (Plate XIV), and from about 2600 to 3900 feet (792 to 1189 m) in Cross Section J-J' (Plate XV). This thickness variation is interpreted as being the result of disharmonic folding of the Santa Susana Formation, the amount of folding being greatest where the formation crops out north of the Marr fault. Where disharmonic folding is not evident on the north side of the fault, the Santa Susana Formation is between 1800 feet (549 m) and 1600 feet (488 m) thick (Cross Section G-G', Plate XIII, and Cross Section L-L', and Plate XVI, respectively).

South of the Marr and Simi faults, the Santa Susana Formation does not exhibit any disharmonic folding, but instead maintains a uniform thickness of approximately

2800 feet (853 m) through the Marr Ranch 26 (#106) well (Figure 3) and the Regent Runkle 1 (#54) well (Cross Section E-E', Plate XI).

In the subsurface, the Santa Susana Formation is a gray siltstone with megafossils, wood fragments, and slickensided fractures present. Union Simi 1-35 (#194) encountered 800 feet (244 m) of Santa Susana Formation that is much sandier than the Santa Susana found in the eastern part of the study area.

Northeast of the study area, Yeats and others (1977) noted that the Santa Susana Formation is found mainly in wells drilled into the hanging-wall block of the Frew fault. Sandstone beds within the Santa Susana in this area are thinner to the southeast and coalesce with the Santa Susana conglomerate to the west. The Santa Susana Formation thins abruptly to 500 feet (152 m) toward the Aliso Canyon oil field (Yeats and others, 1977).

The Santa Susana Formation has been interpreted by Schmidt (1970) as representing a transgressive-regressive marine environment. He believed that the basal Santa Susana siltstone represents the initial marine transgression over the underlying beach and continental deposits of the Marine Paleocene unit and the Simi Conglomerate. Zinsmeister (1974) interpreted the Santa Susana conglomerate as representing a temporary marine regression. The overlying siltstones represent deposition in a continuously subsiding sedimentary basin in which medium to deep water conditions prevailed in an open ocean environment (Browning, 1952; Zinsmeister, 1974). Zinsmeister (1974) interpreted the Meier and Runkle Canyon Tongues as representing coarse sediment influx from the south or southeast under progressively deeper water conditions. The change from calcareous to arenaceous foraminifera in the upper 800 feet (244 m) of the formation indicated a closing off of the basin (Browning, 1952).

On the basis of megafossils, Clark and Vokes (1936) defined the lower Santa Susana siltstones below the Santa Susana conglomerate as belonging to the "Martinez" Stage. The Santa Susana Formation overlying these lower siltstones was referred to the "Meganos" Stage, with the overlying Llajas Formation belonging to the "Capay" Stage. Schmidt (1970) noted that only the upper 300 feet (91 m) of the Santa Susana Formation contain diagnostic megafossils of the "Meganos" Stage. Merriam and Turner (1937) and Merriam (1941) also believed that the upper Santa Susana is "Meganos" and that the "Capay" Stage is restricted to the lower Llajas Formation.

Mallory (1959), based on both megafossil and microfossil evidence, correlated the lower Santa Susana Formation to his Ynezian Stage, the middle Santa Susana with

Bulitian Stage, and the upper 800 feet (244 m) of the formation with his Penutian Stage.

Laiming (1939) used the Santa Susana Formation exposed in the Simi Valley in establishing his foraminiferal zonation for the lower Tertiary of California. He divided the section into the "E", "D", "C", "B-4", and "B-3" zones, in ascending order. Browning (1952) reinterpreted Laiming's classification of the Santa Susana Formation. He pointed out that the "E" zone actually extended up to the middle of the Santa Susana and that the top of the formation was in the "B-4" zone, not the "B-3" zone. Laiming (1939) correlated his "C" zone with the lower "Capay" Stage of Clark and Vokes (1936). A discrepancy arises due to the fact that Laiming correlated his "C" zone with the middle of the Santa Susana Formation whereas Clark and Vokes correlated their "Capay" Stage with the basal Llajas Formation. In addition, Mallory (1959) defined the upper 800 feet (244 m) of the Santa Susana Formation as Penutian, which he considered correlative with the "Capay" Stage. Levorsen (1947) also favored the correlation of the upper Santa Susana to the "Capay" Stage. Schmidt (1970) stated that the inconsistent correlations between the megafossil and microfossil stages may be the result of either an incorrect original correlation between the two classification schemes, or the fact that one or both of the schemes is facies-dependent and transgresses time boundaries. Figure 4

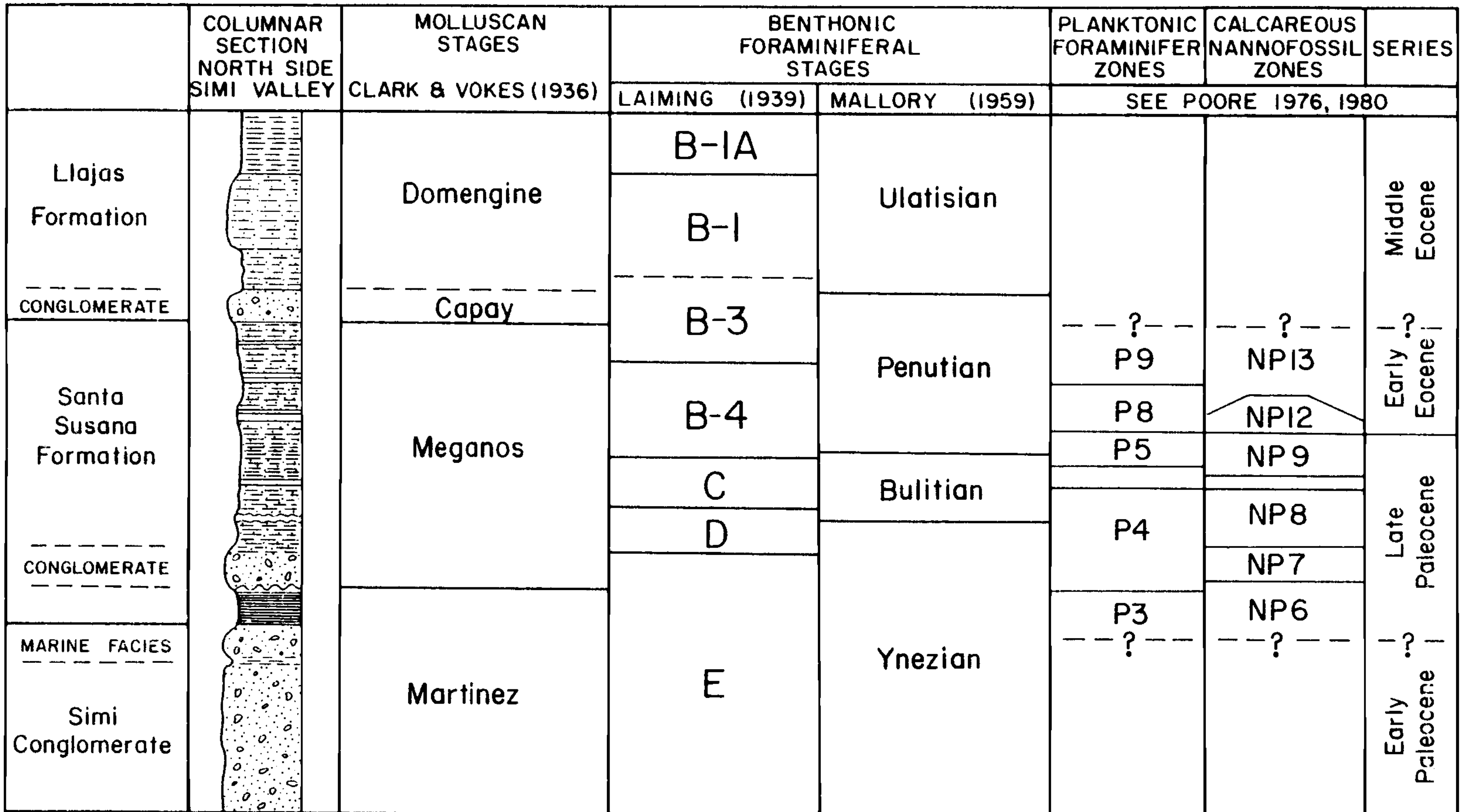

Figure 4 — Stratigraphic chart showing biostratigraphic stages applied to northern Simi Valley section.

presents a summary of the megafossil and microfossil subdivisions and their respective correlations with the lower Tertiary section exposed on the north side of the Simi Valley.

According to Mallory's (1959) classification of the lower Tertiary section exposed on the north side of the Simi Valley, the Paleocene-Eocene boundary lies between the Penutian and Bulitian Stages, about 800 feet (244 m) below the base of the Llajas Formation. Schmidt (1970), in his study of the planktonic foraminifera of the same section, assigned the lower Santa Susana Formation to the *Globanomalina pseudomenardii* Zone and the upper Santa Susana Formation to the *Morozovella velascoensis* Zone. He correlated these zones with the European Landenian Stage, which he defined as the top of the Paleocene. Based on calcareous nannoplankton, Poore (1976) assigned the Santa Susana Formation to the *Heliolithus kleinpellii*, *Discoaster nobilis*, *Discoaster multiradiatus*, and the *Discoaster lodoensis* Zones. These zones are correlated to the NP 6 through NP 13 calcareous nannofossil zones of Martini (1971), and the P 4 through P 9 planktonic foraminifer zones of Berggren (1972), and thereby indicate a late Paleocene to early Eocene age for the Santa Susana Formation (Figure 4) (see Poore, 1980).

Llajas Formation

Rocks presently referred to as the Llajas Formation were first described by Waring (1917) and Kew (1919) as the Tejon Formation. Kew (1924) renamed this sequence the Meganos Formation based upon its faunal similarities with the Meganos Group described by Clark (1918), and not upon a lithologic similarity with the type Meganos. Kew (1924) stated that the base of the Meganos Formation is defined by fossils and not by a change in lithology or by an unconformity. The base of Kew's Meganos Formation lies somewhere in the upper part of the present Santa Susana Formation.

The term "Llajas" was originally an informal name used to designate the marine siltstone, sandstone, and conglomerate underlying the Sespe Formation and cropping out in the vicinity of Las Llajas Canyon. It first appeared in a publication as a footnote by Schenck (1931). McMasters (1933) formally named the Llajas Formation and designated as its type section the exposures along Las Llajas Canyon, northeast of the Simi Valley. This type section was first described in detail by Cushman and McMasters (1936), who also described the Llajas in the subsurface from cores recovered from the Getty Tapo 42 (#186) well (Cross Section G-G', Plate XIII).

Kew (1924) is one of the only workers to correctly correlate the Llajas Formation across the Simi Valley. Other workers correlated the basal Llajas conglomerate on the north side of the valley. An engineering geology report by Leighton and Associates (1972) indicates the presence of a groundwater cascade in the Simi Valley west of, and parallel to Stearns Street. This north-trending feature separates high groundwater to the east from low groundwater to the west, and results from the subsurface blockage of normal east-to-west groundwater flow by a ridge of Llajas conglomerate buried beneath the alluvium of the valley (Figure 5).

In the northeast part of the study area, the Llajas Formation underlies the Pico and Saugus Formations with angular unconformity. Farther north, the Llajas Formation is exposed along the axis of the Llajas Canyon anticline, where it underlies the Modelo Formation with angular unconformity, and is faulted against the Modelo across the north-dipping Joughin reverse fault. At the mouth of Llajas Canyon, Browning (1952) and Mallory (1959) considered the contact between the Llajas and the Santa Susana Formation to be conformable. Stipp (1943) and Levorsen (1947) considered the contact between the two formations to be an erosional unconformity. In addition, the abnormally thick section of Llajas conglomerate overlying the abnormally thin section of Santa Susana Formation southeast of the

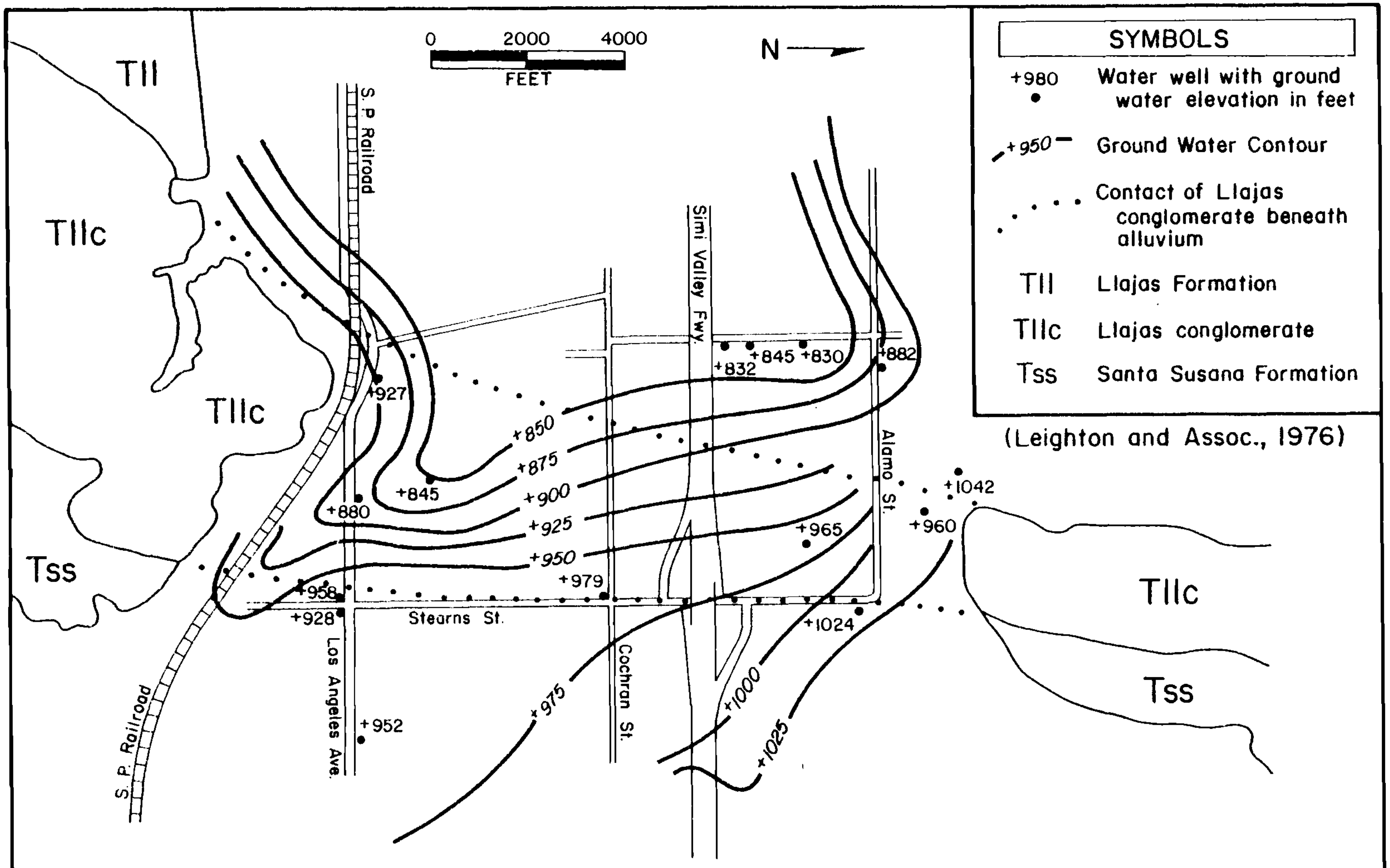

Figure 5 — Contour map of ground water across buried trace of Llajas conglomerate

town of Santa Susana may have resulted from cut-and-fill associated with the deposition of the Llajas conglomerate. This would suggest that the Llajas-Santa Susana boundary is an erosional unconformity.

In outcrop, the Llajas Formation consists of a basal conglomerate overlain by a thick section of interbedded siltstone and sandstone. On the north side of the Simi Valley, the conglomerate varies in thickness from 140 feet (43 m) to 70 feet (21 m). Levorsen (1947) attributed this variation to the erosional relief on the surface of the Santa Susana Formation upon which the Llajas conglomerate was deposited. On the south side of the valley, the conglomerate varies in thickness from about 1500 feet (451 m) southeast of the community of Santa Susana, to 570 feet (174 m) along Meier Canyon. On the southwest side of Meier Canyon, the conglomerate is absent except for a small lens 230 feet (70 m) thick). The Llajas conglomerate gradually becomes more sandy upsection, with the average diameter of conglomerate clasts decreasing upsection from 1 foot to 2 inches.

Overlying the conglomerate is 1620 feet (494 m) of light brown to gray siltstone, sandy siltstone, and fine-grained sandstone. Glauconite is common in sand interbeds in the middle of the formation, and worm impressions and fossil fragments are abundant throughout the formation.

Turbidite sands within the Llajas are found in the western part of the study area in the Gulf Binns 67 (#63), Hancock Strathearn-Coleman 16 (#48), and the Union Simi 3-36 (#219) wells (Cross Sections A-A, B-B'; Plates VII, VIII). These turbidites pinch out to the east and are not seen in the Macson Strathearn 1 (#38) well (Cross Section C-C', Plate IX), but appear to thicken to the west in the Marathon Vail 1 (#69) well (unpublished cross section).

In the subsurface, the thickness of the Llajas Formation varies according to the amount of deformation that it has undergone. South of the Simi fault, the Llajas is consistently about 2000 feet (610 m) thick (Cross Section G-G', Plate XIII), whereas north of the fault the Llajas appears to have undergone disharmonic folding similar to that of the underlying Santa Susana Formation. This is best illustrated in Cross Section H-H' (Plate XIV) where the Llajas varies in thickness from 2100 feet (640 m) along the flank of the anticline to a projected thickness of about 2800 feet (853 m) along the crest of the anticline. The amount of disharmonic folding decreases to the west such that the Llajas Formation north of the Simi fault in the Getty Tapo fee 250 (#189) well and the Getty Tapo Fee 15-A (#188) well, is approximately the same thickness as the undeformed Llajas south of the Simi fault. Farther west, the Llajas Formation is consistently about 2200 feet

(671 m) thick, and it displays none of the disharmonic folding seen in the eastern part of the study area (Cross Section B-B', Plate VIII).

The Llajas conglomerate displays the same variability in thickness in the subsurface as in outcrop. It varies from 170 feet (52 m) thick in the Marr Ranch A-1 (#90) well to 250 feet (76 m) thick in the Pacific Western Marr 1 (#179) well. The pinch out of the conglomerate southwest of Meier Canyon is illustrated in Cross Section E-E' (Plate XI), where the conglomerate varies from 300 feet (91 m) thick in the Regent Runkle 1 (#54) well, to zero in outcrop. The Llajas conglomerate thins and appears to become less conglomeratic westward in the Hancock Strathearn-Coleman 16 (#48) and the Union Simi 3-36 (#219) wells (Cross Section B-B', Plate VIII). To the northeast, it becomes more sandy in the Las Llajas oil field (Cross Section L-L', Plate XVI).

In the Camarillo Hills, Jakes (1979) reported 1300 feet (396 m) of Llajas strata in the Lloyd Livingston 4 well (Sec. 31, T. 2N. R. 21W.). Recorrelation of this well with wells in the study area indicates that the Llajas Formation is actually 2200 feet (671 m) thick in the Camarillo Hills. In the Big Mountain area, Canter (1974) reported 2940 feet (896 m) of Llajas Formation in the subsurface. Northeast of the study area, Yeats and others

(1977) reported that the Llajas Formation is 1700 feet (518 m) thick south of the Frew fault and 1200 feet (366 m) thick north of the Frew fault. In the western part of the Aliso Canyon oil field, the unconformity at the base of the Modelo Formation truncates the Llajas so that its thickness is 250 feet (76 m) (Lant, 1977); farther east, the Modelo overlaps the Llajas and rests on the Santa Susana Formation. In the western San Fernando Valley, Shields (1977) reported an undifferentiated sequence of Llajas and Santa Susana Formations up to 2800 feet (853m) thick.

Based on molluscan fauna, Clark and Vokes (1936) assigned the Llajas Formation to the lower Eocene "Capay" Stage and the middle Eocene "Domengine" Stage (Figure 4). Merriam and Turner (1937) restricted the "Capay" Stage to the basal Llajas conglomerate and the remainder of the formation to the "Domengine" Stage. Laiming (1939) correlated the Llajas Formation with his "B-3" through "B-1A" zones. Mallory (1959) stated that the bulk of the Llajas Formation belongs to the Ulatisian Stage, with the basal conglomerate correlative with the upper Penutian Stage. In addition, the uppermost Llajas in the Carlsberg Estes 1 (#29) well (Cross Section E-E', Plate XI) was determined to be Narizian in age.

Sespe Formation

The Sespe Formation was first described as the "Sespe brownstone" by Watts (1897) for a 3500 foot (1067 m) thick section of brown sandstone, shale, and conglomerate exposed along lower Sespe Creek near Fillmore, California. Kew (1924) extended the Sespe Formation to include all upper Eocene to lower Miocene continental redbeds throughout the Ventura Basin. The stratigraphy and occurrences of petroleum within the formation were discussed by Bailey (1947).

The contact between the Sespe Formation and the underlying Llajas Formation was reported by Kew (1924) to be an unconformity. Stipp (1943) stated that the contact is conformable, while in the Tapo Canyon area, Hetherington (1957) reported that the contact is disconformable. Subsurface data from the western and central part of the thesis area imply a gradational contact between the two formations. In the northeast corner of the study area, however, Cross Section L-L' (Plate XVI) documents the presence of an angular unconformity between the Sespe and Llajas Formations.

For the purpose of lithologic description, the Sespe Formation exposed in the Simi Valley area is divided into a lower and an upper member. The lower member, exposed on the south side of the valley, is composed of yellow sandstone and siltstone with lenses of pebble-to-cobble conglomerate. In the subsurface, this member is greenish gray and is difficult to distinguish from the underlying Llajas Formation. The upper member is composed of alternating beds of white sandstone and green to red siltstone and claystone.

Correlation of the Sespe Formation in the subsurface was accomplished using electric log markers that are best defined in the Carlsberg Estes 1 (#29) well (Cross Section E-E', Plate XI). Of these, the 17-3 and the LSO-'73' markers are the most distinctive and can be recognized throughout the thesis area. The remaining electric log markers can also be recognized in the area, but with a greater degree of difficulty.

In the study area, the Sespe Formation attains a maximum thickness of 5900 feet (1798 m) in the Union Simi 1-26 (#191) well. It thins to 5000 feet (1524 m) thick in the South Tapo Canyon area (Hetherington, 1957), and pinches out beneath the Modelo Formation east of Las Llajas Canyon. The eastward thinning of the formation is due to post-Sespe erosion and not intra-Sespe thinning. The thickness of the interval between the 17-3 intra-Sespe marker and the base of the Sespe varies from 2900 feet (884 m) in the Union Simi 1-26 (#191) well to approximately 2600 feet (792 m) elsewhere in the area. An intra-Sespe isopach map done by Canter (1974) demonstrated a relatively uniform thickness throughout the Big Mountain area to the north.

West of the study area, Jakes (1979) reported that the Sespe Formation varies in thickness from 6500 feet (1981 m) in the northwest Camarillo Hills to zero in the Las Posas Hills, south of the Simi fault. This rapid thinning is attributed to truncation of the Sespe by erosion and by normal faulting. Ricketts and Whaley (1975) reported intraformational thinning from west to east in the eastern part of Oak Ridge. They attributed this to the existence of a structural high during the time of upper Sespe deposition, resulting in either nondeposition, or intraformational erosion of a part of the upper Sespe.

McCracken (1972) interpreted the lower Sespe conglomerate and sandstone to be alluvial fan deposits laid down by a braided river system. The upper sandstone and mudstone are interpreted as channel, point bar, and floodplain deposits laid down by a meandering river system. Bailey (1947) stated that the axis of maximum Sespe sedimentation extends from a point north of the Simi Valley, west-northwest through South Mountain, to a mile north of Carpinteria.

South of the Santa Clara River, the Sespe Formation ranges in age from late Eocene (Uintan) to early Miocene (Arikareean) based upon vertebrate remains (Stock, 1932;

Wilson, 1949; Savage and Downs, 1954; Durham and others, 1954). To the west, in the Las Posas Hills, Stock (1932) identified late Oligocene (Whitneyan) vertebrate fossils.

Vaqueros Formation

The Vaqueros Formation was first defined by Hamlin (1904) for a coarse-grained, quartzose sandstone exposed in Los Vaqueros Canyon on the eastern slope of the Santa Lucia Range in the central Coast Range. Eldridge and Arnold (1907) extended the Vaqueros Formation north and south of the Santa Clara River to include 3000 feet (914 m) of predominately lower Miocene marine strata. Kew (1924) redefined the Vaqueros Formation to include only those "beds of a sandy nature" which contain lower Miocene fauna similar to that present in the Vaqueros Formation at its type locality in Los Vaqueros Canyon.

The Vaqueros Formation is exposed in the northwest corner of the study area along the southern flank of Big Mountain. Kew (1924) and Van Camp (1959) reported the contact between the Vaqueros and the Sespe Formations as being conformable. Hall and others (1967) and Canter (1974) demonstrated the presence of an unconformity through the Big Mountain oil field, based in part on post-Sespe, pre-Vaqueros normal faults there. The Vaqueros thins from west to east until it is truncated and overlapped east of Alamos Canyon by the Topanga Formation (Canter, 1974). Surface exposures of the Vaqueros Formation in the study area are up to 464 feet (141 m) thick and are composed of light gray to light brown, massive, fossiliferous, coarse-grained sandstone.

In the subsurface, the Vaqueros is 300 feet (91 m) thick in the Union Moorpark 1-34 (#193) well (Cross Section F-F', Plate XII) and 450 feet (137 m) thick in the Union Simi 1-26 (#191) well (Cross Section A-A', Plate VII). The presence of the Vaqueros Formation in the Union Moorpark 1-34 (#193) well is based on correlation with the Lytle Williams 2 well (Sec. 33 T. 3N. R. 19W.).

Conejo Volcanics

The Conejo Volcanics were first named by Taliaferro (1924) for the Miocene volcanic rocks exposed in the western Santa Monica Mountains. He also noted that the volcanics are locally interbedded with marine sedimentary rocks of the Topanga Formation. The volcanics essentially consist of alternating andesitic and basaltic breccias and flows that are interbedded locally with fossiliferous, epiclastic sandstone and siltstone. A black, shaly marine siltstone containing abundant fish scales is present at the base of the volcanics in some parts of the Santa Monica Mountains (Yerkes and Campbell, 1979). In the Conejo Hills, Williams

(1977) reported a succession of submarine pillow basalt, hyaloclastic pillow breccia, and autoclastic breccia, grading upward to subaerial basalt and andesite flows and pyroclastic breccias.

In the study area, the Conejo Volcanics occur on the southwest flank of Big Mountain and in Tierra Rejada Valley. In the Big Mountain area, the volcanics unconformably overlie the Vaqueros Formation and interfinger with and are overlain by the Topanga Formation. Van Camp (1959) reported that these volcanics consist of dark brown to black porphyritic basalts that pinch out abruptly to the north and east. Cushman and Leroy (1938), and Hall and others (1967) believed that these basalts are extrusive. The presence of small apophyses of basalt intruding into the overlying Topanga Formation led Van Camp (1959) to suggest that the basalt is a sill.

In Tierra Rejada Valley, the Conejo Volcanics unconformably overlie the Sespe Formation south of the Simi fault with little angular discordance (Cross Section A-A'. B-B'; Plate VII and VIII). North of the fault, the volcanics overlie the Sespe with an angular discordance of up to 20°. A subcrop map of the Sespe electric log markers beneath the volcanics indicates that folding and erosion of the Sespe on the north side of the Simi fault preceded the deposition of the Conejo Volcanics (Figure 6).

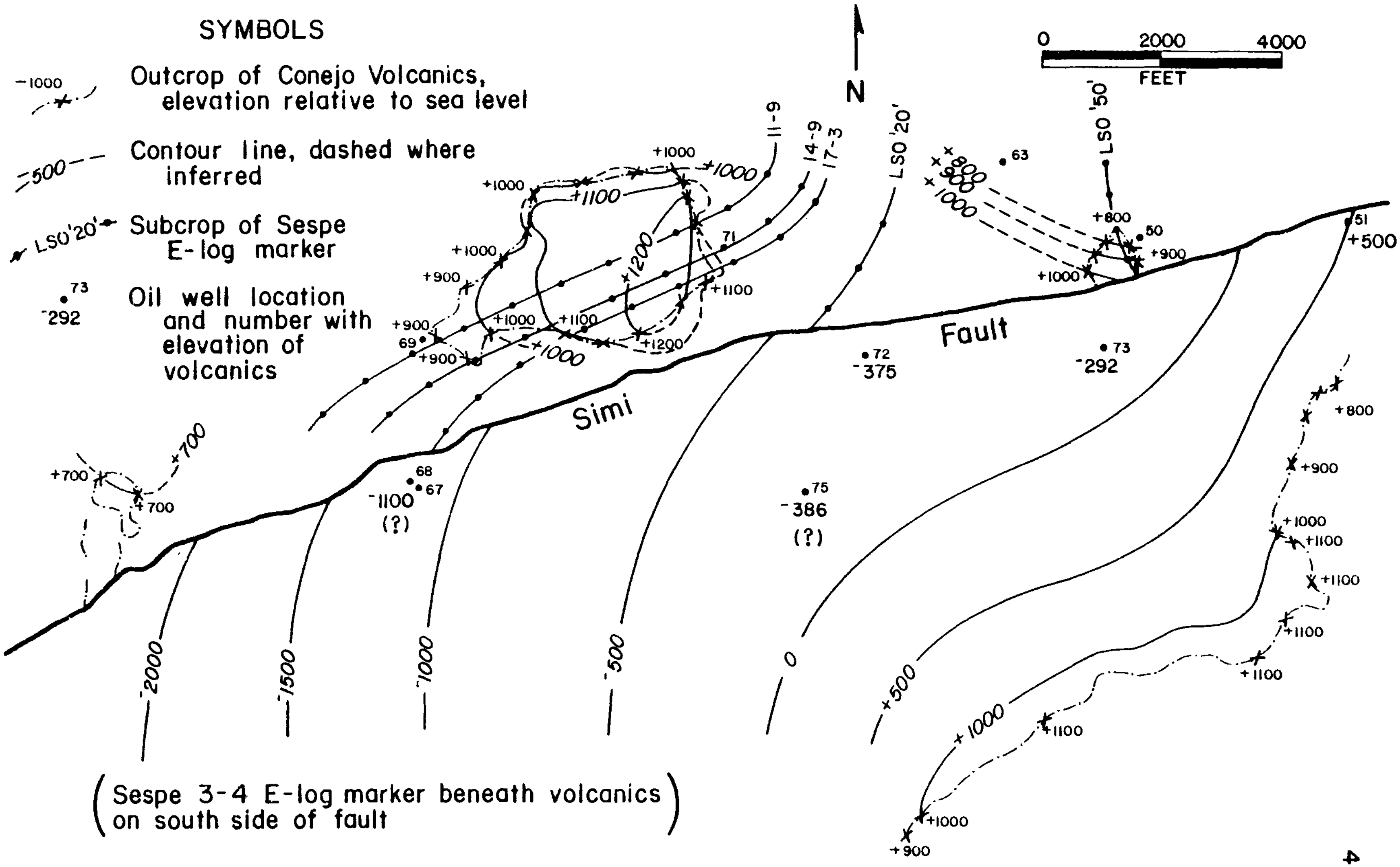

Figure 6 – Structure contour map of base of Conejo Volcanics with subcrop of Sespe electric log markers

In Tierra Rejada Valley, the volcanics consist of nonvesicular, vesicular, and amygdaloidal basalt flows, breccias, and dikes. Most of the flows and dikes are extensively fractured and jointed. In the subsurface, the Conejo Volcanics range in thickness from approximately 1150 feet (351 m) in the McAllister Strathearn-Coleman 1 (#72) well to 50 feet (15 m) in the R&R Strathearn 11 (#51) well. The volcanics in the R&R Strathearn 11 (#51) well represent the most easterly occurrence of the volcanics south of the Simi fault. In the subsurface, sidewall and ditch descriptions of wells drilled into the volcanics indicate an interfingering relationship with the sandstone and siltstone of the Topanga Formation.

To the west, in the Camarillo and Las Posas Hills area, Jakes (1979) did not differentiate between the Conejo Volcanics and the Topanga Formation due to their complex interfingering. She noted an abrupt increase in thickness of the volcanics on the south side of the Simi fault, which she interpreted as being the result of a ponding of the volcanics against a pre-Conejo scarp in the Sespe Formation. Jakes (1979) stated that these scarps most likely formed by subsidence of the Sespe toward a volcanic center in the Conejo Hills.

South of the Simi fault in the study area, the Conejo Volcanics gradually thicken to the southwest without the anomalously large thickness that is seen in the Camarillo and Las Posas Hills area. The volcanics on the north side of the Simi fault appear to be erosional remnants, possibly originally continuous with the volcanics exposed on the southwest flank of Big Mountain.

Potassium-argon age determination of plagioclase separates from the Conejo Volcanics in the Santa Monica Mountains range from 15.5±0.8 m.y. near the base, to 13.9±0.4 m.y. near the top of the volcanics (Turner and Campbell, 1979). An andesite sample from the south side of the Simi fault, in the vicinity of Arroyo Santa Rosa, gave an age of 13.9±0.4 m.y. (Turner and Campbell, 1979), indicating that the volcanics in the Tierra Rejada Valley represent a very late phase of Conejo eruptions.

Topanga Formation

The Topanga Formation was originally described in the Thousand Oaks area by Kew (1919). He later named it the Topanga Formation after Topanga Canyon in the Santa Monica Mountains (Kew, 1924). Cushman and Leroy (1938) identified the Topanga in the Big Mountain area on the basis of its stratigraphic position and its angular discordance with the underlying Vaqueros Formation. Susuki (1952) recognized a series of intercalated basalts within the Topanga in the Santa Monica Mountains. Durrell (1954) divided the Topanga at this location into three members: a lower member of marine sandstone and siltstone, a middle member of basalt, volcanic breccia, and interbedded fossiliferous sandstone, and an upper member of marine sandstone and siltstone. Yerkes and Campbell (1979) proposed that Topanga be the group name for the thick sequence of middle Miocene marine and nonmarine sedimentary and volcanic rocks exposed in the Santa Monica Mountains.

In the Simi Valley area, the Topanga Formation is exposed along the southern flank of Big Mountain and in isolated outcrops in Tierra Rejada Valley. On the south flank of Big Mountain, the Topanga overlies the Vaqueros and Sespe Formatons with an angular unconformity of 10° to 12° (Canter, 1974). Canter (1974) also noted that the Topanga unconformably overlies the Conejo Volcanics. The thickness of the Topanga Formation in this area varies from 500 feet (152 m) northwest of the Union Simi 1-26 (#191) well to zero where it pinches out beneath the Modelo Formation northwest of Dry Canyon. It is composed of a basal, interbedded sandstone and conglomerate overlain by a fine- to medium-grained, micaceous sandstone. On fresh exposures, the Topanga is yellow to gray in color and weathers to a red brown color.

In Tierra Rejada Valley, the Topanga occurs as isolated erosional remnants unconformably overlying the Conejo Volcanics. Descriptions of drill cuttings indicate that the yellow claystone and gray sandstone of the Topanga are interbedded with the Conejo Volcanics. This interbedded relationship is not illustrated in cross sections in this study due to the difficulty of separating the two formations in the subsurface.

In the Camarillo and Las Posas Hills area, Jakes (1979) did not differentiate the Conejo Volcanics and the Topanga Formation due to their interbedded nature and the presence of cross-cutting volcanic intrusions. To the northeast of the study area, Yeats and others (1977) reported that the Topanga is present only in the hanging-wall block of the Santa Susana fault. They noted that at least 1500 feet (451 m) of the formation is present, with the base cut out by the Santa Susana fault; where it is not cut out by the fault, the Topanga Formation overlies basement rocks (Yeats, 1979). To the east of the study area, Shields (1977) reported that the Topanga is 2000 feet (610 m) thick in the subsurface south of Chatsworth Reservoir. The formation thins to the north, as the overlying angular unconformity between the Modelo Formation truncates progressively older Topanga strata. North of the Santa Susana fault, however, Lant (1977) indicated that the Topanga-Modelo contact is conformable.

To the northeast of the study area, Yeats and others (1977) and Lant (1977) stated that the Topanga Formation contains only Luisian (middle Miocene) fossils. To the west, Jakes (1979) reported of Saucesian and Relizian (lower to middle Miocene) microfauna from subsurface cuttings. The dated Conejo Volcanic sample from the Arroya Santa Rosa (13.9±0.4 m.y.; Turner and Campbell, (1979) indicates that the interbedded Topanga strata in the Tierra Rejada Valley is Relizian to Luisian in age.

Modelo Formation

Eldridge and Arnold (1907) first named the Modelo Formation for a 10,000 foot (3048 m) thick section of sandstone and mudstone exposed in Modelo Canyon, near Piru, California. Kew (1924) later redefined the Modelo to include an upper, late Miocene to early Pliocene sandstone that was later named the Towsley Formation by Winterer and Durham (1954). The Towsley is not exposed in the study area, but crops out north of the Santa Susana fault.

In the Simi Valley area, the Modelo Formation is exposed along the axis of Happy Camp syncline as well as along the crest of Big Mountain. Its base is an unconformity throughout the study area. Van Camp (1959) reported an angular discordance of 6° to 8° between the Modelo and the underlying Sespe Formation, just south of Big Mountain. To the east, near Tapo Canyon, the discordance increases to 15° (Hetherington, 1957). Along the axis of Happy Camp syncline, near Las Llajas Canyon, the Modelo overlies both the Sespe and Llajas Formations with angular unconformity (Cross Section L-L', Plate XVI).

In the Simi Valley area, the Modelo Formation can be divided into a gray to brown, fine-grained, silty, basal sandstone containing worm impressions and fish scales, and an overlying gray to brown, diatomaceous claystone and siltstone that weathers white. The basal sandstone is locally absent.

Jakes (1979) reported that the Modelo Foramtion is present in the subsurface in the vicinity of the Camarillo Hills, and that it thins eastward and is overlapped by the Saugus Formation toward the Las Posas Hills; isolated outcrops of Modelo were mapped in the eastern Las Posas Hills, however. Northeast of the study area, Yeats (1979) noted that abrupt facies variations within the Modelo

Formation occur across the Santa Susana fault, and the the Modelo north of the fault is 2 to 3 times thicker than the Modelo south of the fault.

Siltstone interbeds within the basal sandstone have yielded foraminifera of middle Miocene (Luisian) age (Yeats and others, 1977). Canter (1974) reported that the age of the upper Modelo in the Big Mountain area is middle to upper Miocene (Luisian to Mohnian). Paleontologic data from wells drilled in the Camarillo Hills area indicate a middle to late Miocene (Luisian to Mohnian) age for the Modelo Formation.

Pico Formation

Rocks of the Pico Formation were first described by Elderidge and Arnold (1907) as part of the Fernando Formation. Kew (1924) redefined the Fernando as a group, and divided it into the Pico and Saugus Formations. Oakeshott (1958) separated Kew's Pico Formation into the early Pliocene Repetto Formation and the middle to upper Pliocene Pico Formation. Winterer and Durham (1962) renamed the Repetto the Towsley Formation, and assigned the upper member of the Pico Formation (the Sunshine Ranch member) to the overlying Saugus Formation.

The Pico Formation crops out along the flanks of the Happy Camp syncline, in the northeastern part of the study area, where it unconformably overlies the Modelo, Sespe, and Llajas Formations. North of the Santa Susana fault, the Pico rests conformably on the Towsley Formation.

In the study area, the Pico Formation reaches a maximum thickness of 600 feet (183 m). It consists of a light gray, fossiliferous sandstone, with conglomerate and coquina beds common near the middle of the formation. Yeats and others (1977) noted that the subsurface Frew fault was active during Pico deposition, and that it separates a thick sequence of Pico north of the fault from a thin sequence south of the fault.

Yeats and others (1977) suggested that the blocky electric log character and the sparse megafauna of the Pico Formation in the Santa Susana Mountains indicates that the Pico was deposited as a submarine fan in a rapidly subsiding basin. In the study area, a shallow-water environment of deposition is indicated by a brachiopod assemblage described by Squires (1977) in Browns Canyon.

Saugus Formation

The Saugus Formation was first defined by Hershey (1902) for a 2000-foot (610 m) exposure of unconsolidated nonmarine sand, gravel, and clay in Soledad Canyon, near Saugus, California. Eldridge and Arnold (1907) later included these rocks in their Pliocene Fernando Formation. Kew (1924) elevated the Fernando to group status and divided it into the early Pliocene Pico Formation and the late

Pliocene Saugus Formation. Pressler (1929), in describing the Fernando Group in the Las Posas-South Mountain area, referred to the Saugus as the Las Posas Formation based on its marine character. Jakes (1979) stated that Las Posas is a local term used in the Las Posas Hills, and that the term Saugus more clearly describes the marine Pleistocene rocks in this area. Winterer and Durham (1962) divided the Saugus of the eastern Ventura basin into a lower, brackish-water to shallow-marine Sunshine Ranch Member and an unnamed upper, nonmarine member. Oakeshott (1958) and Canter (1974) incorrectly described the Sunshine Ranch as the upper member of the Pico Formation.

The Saugus Formation is exposed along the northern margin of the study area (Plate I). In the northwestern corner, the Saugus overlies the Topanga, Conejo Volcanics, Vaqueros, and Sespe Formations with angular unconformity. The lower marine member of the Saugus is present near Moorpark College and on the west flank of Big Mountain. To the east, and locally to the southwest at Virginia Colony, the nonmarine Saugus rests directly upon older strata, mainly Sespe Formation. Along the southern and southeastern margin of Big Mountain, the marine Saugus overlies the Modelo Formation with angular unconformity. In the northeast corner of the study area, the marine Saugus unconformably overlies the Pico, Modelo, and Llajas

Formations. Yeats and others (1977) observed an angular discordance of 20° between the Saugus and Pico Formations at the head of Browns Canyon.

The absence of the marine Saugus member north of the Oak Park oil field and its presence to the west, northeast, and east suggests that this area was a topographic high, and possibly a structural high during the time of Saugus deposition. The apparent absence of the Saugus south of the Simi fault precludes any correlations about this high being related to early movement on the Simi fault, as was concluded by Jakes (1979) in the Las Posas Hills to the west.

The Saugus Formation consists of coarse-grained arkosic sandstone and conglomerate. The lower marine member consists of white, fairly well sorted sandstone, coquina, and conglomerate. The Saugus ranges in thickness from 100 feet (30 m) in the Union Simi 1-26 (#191) well, to an inferred thickness of 350 feet (107 m) in the Union Moreland Investment 1 (#192) and the Union Moorpark 1-34 (#193) wells. The Saugus thickens to the west to about 700 feet (213 m) in the Moorpark oil field (Canter, 1974), and about 600 feet (183 m) in the Camarillo Hills (Jakes, 1979). To the east, along the axis of the Happy Camp syncline, the marine member attains a maximum thickness of 400 feet (122 m) (Yeats and others, 1977).

Anorthosite clasts within the Saugus Formation indicate a source area in the San Gabriel Mountains. In Horse Flats, east of the study area, the change in clast composition upsection to fragments of the Towsley and Modelo Formations is assumed to indicate the beginning of the uplift of the Santa Susana Mountains (Saul, 1975).

Yeats and others (1977) considered the lower marine member of the Saugus Formation to be an interfingering marine, brackish-water, and nonmarine deposit. Fossils found at the eastern end of the Las Posas Hills by Pressler (1929) indicate a Pleistocene age for the Saugus in that area.

Older Alluvium

Older alluvium is located along the margins of the Simi Valley as well as in the hills in the vicinity of the Oak Park and Canada de la Brea oil fields. Old alluvium includes the gravels, sands, and silts of stream terraces and older alluvial fan deposits that are generally more consolidated than the younger alluvium.

In the area east of Moorpark, older alluvium blankets the upper part of southwest-facing hillslopes, where it overlies Saugus and rests on the Sespe Formation. The widespread distribution of older alluvium suggests that this area was the site of a broad aggrading plan or alluvial fan that was later dissected by Alamo and Brea Canyons, and the canyons to the east and west. The downcutting may have been caused by movement along the Simi fault with the resulting uplift of the Big Mountain area, or it may be related to the emplacement of the Arroyo Simi between Moorpark and the Simi Valley, where it cuts across the Simi fault in the Strathearn oil field.

The Tierra Rejada trench (T_3), dug across the Simi fault, encountered old alluvium that was interpreted to be "significantly older" than the 4050±100 year old alluvial fan deposits dated in the Murphy trench (T_4) (Envicom Corp., 1976). As a result, this old alluvium was inferred to be pre-Holocene in age, or at least 11,000 years old (Envicom Corp., 1976).

Landslides

Landslides are located throughout the highlands surrounding the Simi Valley, especially on dip slopes. The landslides mapped in this area are predominately bedrock slides, with components of slump or block glide (California Division of Mines and Geology, open file report 76-5 LA, 1975). The landslides do not appear to be localized within a particular formation.

Younger Alluvium

Younger alluvium occurs extensively in the study area, flooring the Simi Valley as well as the canyons that radiate from the valley. The alluvium is composed of silts, sands, and gravels that represent colluvium, slope wash, floodplain, and stream channel deposits. Water well and oil well data indicate that the alluvium reaches a thickness of 500 to 600 feet (152 to 183 m) in the central part of the valley (Leighton and Assoc., 1972) (Figure 7); part of this sequence may be older alluvium or Saugus Formation. In Cross Section G-G' (Plate XIII), 460 feet (140 m) of yellow clay, gravel, and boulders overly the Sespe Formation in the Jesse C. Barnes Ricoute 1 (#23) well. In Cross Section H-H' (Plate XIV), the electric log character of the Northridge Simco 1 and 2 (#100, #101) wells clearly indicates the thickness of the alluvium overlying the Llajas Formation.

Cross section B-B' in Figure 7 indicates that the original channel for the Arroyo Simi was in the middle of the Simi Valley, and that as the valley was filled with alluvium, the Arroyo Simi was forced along the southern margin of the valley. Groundwater contours across the Llajas conglomerate (Figure 5) show a northwest-trending depression 50 to 75 feet (15 to 23m) deep cutting across the conglomerate in the vicinity of the present Arroyo Simi. This suggests a period of downcutting by the Arroyo Simi, forming a narrow gorge through the conglomerate,

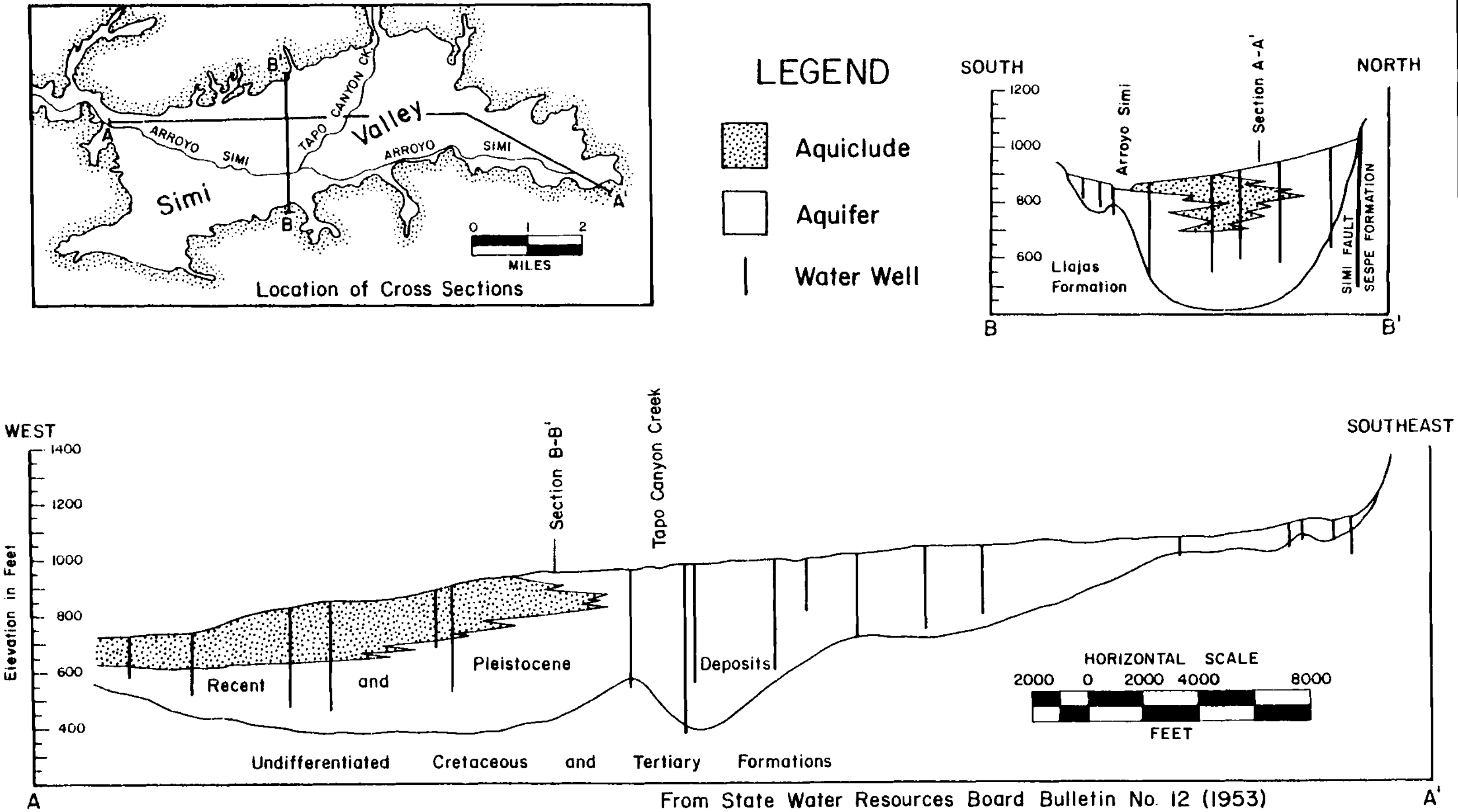

Figure 7—Cross section of Simi Valley alluvium

which was followed by a period of aggradation where the gorge was filled with 100 to 150 feet (30 to 46 m) of alluvium. The period of downcutting may represent a time during which the Arroyo Simi had an outlet from the Simi Valley. The following period of aggradation may then reflect a closing-off of the outlet, possibly resulting from movement along the Simi fault.

The Murphy trench (T_4), dug across the Simi fault, encountered a number of old erosional surfaces, gravel beds, and preserved soil horizons in the alluvium. Radiometric dating of caliche ($CaCO_3$) nodules from the oldest soil horizon indicated an age of 4050±100 years (Envicom Corp., 1976).

STRUCTURE

Introduction

The history of faulting in the Simi Valley area is similar to the history of faulting in the Oak Ridge-Santa Susana Mountains area. In the study area, the south-dipping Brugher, Llajas, Ybarra Canyon, and Marr faults have the same geometry and age relations as the subsurface Frew fault to the north and northeast. These south-dipping faults are all unconformably overlain by the Saugus Formation, except for the Ybarra Canyon fault, which may actually be pre-Saugus in age (see Geologic History section).

In the Oak Ridge-Santa Susana Mountains area, the south-dipping Frew fault is cut by the north-dipping Roosa fault, which is also pre-Saugus in age. In the study area, the north-dipping C.D.L.B. and Strathearn faults have the same geometry as the Roosa fault, and are also pre-Saugus in age. An age relationship between the C.D.L.B. and Strathearn faults and the south-dipping faults in the study area cannot be determined from available data.

The north-dipping proto-Simi fault does not have a correlative in the Oak Ridge-Santa Susana Mountains area because it predates the south-dipping Marr fault. The Simi fault cuts the Marr fault suggesting that it may be correlative with the Roosa fault, but the Simi fault also has a post-Saugus period of movement.

Simi Anticline

Throughout most of its length, the Simi anticline trends southwest-northeast, parallel to the Simi fault. East of Tapo Canyon, the anticline is located on the north side of the Marr fault and no longer parallels the Simi fault. The Simi anticline has a variable plunge: it forms a dome in the Strathearn oil field, plunges west in the Simi oil field, and forms a dome north of the Marr fault. The fold is asymmetric, with a gently dipping north limb and a steeply dipping south limb. East of Tapo Canyon, however, the north limb steepens considerably. To the west, near vertical to overturned dips on the south limb of the anticline indicate drag folding along the Simi fault (Figure 9).

Plates VI and V indicate that north of Tierra Rejada Valley the south limb of the Simi anticline is cut by the Simi fault, and that the amount of truncation decreases to the east. East of Tapo Canyon, the south limb of the fold is cut by the proto-Simi, Marr, and Simi faults, with the amount of truncation also decreasing to the east. Offset of the anticline across Tapo Canyon is due to east-side-up movement along the fault located beneath Tapo Canyon.

In the study area, the Simi anticline is cut by the proto-Simi and Simi faults, indicating formation of the anticline prior to movement on the faults. The anticline folds the Sespe Formation, but appears to fold the overlying Conejo Volcanics to a much lesser degree (Figure 6). There is no evidence for post-Saugus folding along the Simi anticline in the study area.

Llajas Canyon Anticline

The Llajas Canyon anticline is a sinuous fold that extends from the Santa Susana fault westward to where it dies out in the Modelo Formation. The eastern and western segments of the fold are parallel to the Happy Camp syncline, whereas the middle segment trends at an oblique angle to the syncline. On the north flank of the Llajas Canyon anticline, the dip of the Saugus Formation is less than the dip of the underlying Llajas and Modelo Formations, indicating a period of pre-Saugus and post-Saugus folding. The Llajas Canyon anticline is offset by the Joughin fault.

Happy Camp Syncline

The Happy Camp syncline extends from Grimes Canyon eastward along the southern flank of Oak Ridge and the Santa Susana Mountains, to just beyond the Ventura-Los Angeles County line. In the study area, the syncline trends northwest-southeast and plunges to the northwest. Mapping in the Big Mountain area indicates that the Happy Camp syncline is asymmetric, with a steep south limb and a gently dipping north limb (Canter, 1974). Plate I indicates that the Happy Camp syncline folds strata as old as the Llajas Formation, and as young as the marine member of the Saugus Formation. The parallel alignment of the fold with the Santa Susana fault implies that the two structures may be contemporaneous.

Proto-Simi Fault

On the north side of the Marr fault, the Marr Ranch 19 (#98) well and the Shell Marr 1 (#102) well are both cut by a north-dipping reverse fault that is not exposed at the surface due to truncation by the Marr fault (Cross Sections H-H' and I-I'; Plate XIV). This north-dipping reverse fault trends southwest-northeast, dips 80° to 85° north (Plate III), and is referred to as the proto-Simi fault.

The proto-Simi fault is defined in the subsurface by the repetition of faunal markers in the Marr Ranch 19 (#98) well and the Shell Marr 1 (#102) well. Separation across the fault in these two wells is approximately 1300 feet (396 m). To the east, the separation across the fault decreases to approximately 800 feet (244 m) in Cross

Sections J-J' and L-L' (Plates XV-XVI).

In Cross Section G-G' (Plate XIII), the 1170 feet (357 m) of observed separation across the Simi fault is anomalously large when compared to the 850 feet (259 m) of separation in an unpublished cross section to the west, and the 230 feet (70 m) of separation in Cross Section H-H' (Plate XIV). This implies that the proto-Simi fault is coincident with the Simi fault in Cross Section G-G'. An estimated displacement of 630 feet (192 m) on the Simi fault in this cross section indicates a separation of 540 feet (165 m) on the proto-Simi fault. The proto-Simi fault appears to merge with the Simi fault westward through the study area (see discussion of Simi fault).

Ybarra Canyon Fault

The western half of the Ybarra Canyon fault is a south-dipping reverse fault that brings the Simi Conglomerate against the Santa Susana Formation. This part of the fault trends east-west and joins the Llajas and Marr faults at its western end (Plate I).

The eastern half of the Ybarra Canyon fault trends northwest-southeast, parallel to the Happy Camp syncline. East of Devil Canyon, the fault juxtaposes the Simi Conglomerate against the marine member of the Saugus Formation, brings Simi Conglomerate against Simi Conglomerate, and cuts the marine Saugus. The eastern part of the Ybarra Canyon fault dips 45° to 70° north while still displaying a south-side-up displacement. Separation along this part of the fault is normal, but its amount is unknown.

The change in dip of the eastern half of the Ybarra Canyon fault may be the result of overturning of the fault plane that occurred during folding of the Saugus Formation northeast of the fault. A comparable situation exists in the Aliso Canyon area, where Lant (1977) reported that the south-dipping Frew fault is folded to a steeper south dip by the Santa Susana fault. In addition, near Torrey Canyon oil field, Ricketts and Whaley (1975) showed that the South Strand of the Oak Ridge fault has been rotated to a north dip with normal separation by movement on the younger Santa Susana fault.

Llajas Fault

The western half of the Llajas fault was reported by Bishop (1950) to be a south-dipping reverse fault that juxtaposes the Santa Susana Formation against the Llajas and Pico Formations. This western half trends east-west and joins the Ybarra Canyon and Marr faults at its western end. The eastern half of the fault trends northwest-southeast and dips 70° to the north (Plate I).

East of Devil Canyon, the fault is covered by the marine member of the Saugus Formation. Bishop (1950) reported the displacement on the Llajas fault to be 400 to 1500 feet (122 to 457 m) with the greatest displacement to the west. As with the Ybarra Canyon fault, the change in dip of the eastern half of the Llajas fault may be the result of overturning of the fault plane that occurred during folding of the Saugus Formation northeast of the fault.

Brugher Fault

The Brugher fault was first mapped by Cabeen (1939) as a south-dipping reverse fault that brings the Llajas Formation against the Modelo and Pico Formations. The fault trends northwest-southeast and dips 50° to 62° (Plate I). At its western end, the Brugher fault does not offset the marine member of the Saugus Formation, which overlies the fault.

Cabeen (1939) and Lewis (1940) described a narrow strip of Modelo exposed on the north side of the fault as a Modelo "dike." Lewis (1940) interpreted the numerous south-dipping fractures within this "dike" as being fracture planes along which the Modelo moved as drag along the Brugher fault.

Marr Fault

The Marr fault is an east-west trending reverse fault that dips 80° to 87° south. The fault extends from its juncture with the Llajas and Ybarra Canyon faults westward to where it is truncated by the Simi fault, 3000 feet (914 m) east of Tapo Canyon. Plate I illustrates that the western half of the Marr fault has an apparent normal separation, while the eastern half of the fault displays a reverse separation. Cross Section H-H' and I-I' (Plate XIV) indicate that the apparent normal separation on the western half of the fault is the result of the reverse displacement on the concealed proto-Simi fault. Subsurface control on the Marr fault is absent.

Inferred vertical separation on the Marr fault varies from 830 feet (253 m) in Cross Section H-H' (Plate XIV) to 1600 feet (488 m) in Cross Section L-L' (Plate XVI). The fault appears to die out west of its intersection with the Simi fault since it is not seen in Cross Section G-G' (Plate XIII). In the subsurface, the Marr fault truncates the proto-Simi fault and is itself cut by the Simi fault (Cross Section I-I', Plate XIV). The Marr fault appears to be the westward continuation of the Llajas and Ybarra Canyon faults.

Corredo Fault

The Corredo fault extends from its juncture with the Ybarra Canyon fault southeast to where it apparently dies out in Upper Cretaceous strata (Plate I). The fault trends northwest-southeast parallel to the Happy Camp syncline, displays a south-side-up separation, and juxtaposes Upper Cretaceous strata against the Simi Conglomerate.

Bishop (1950) believed the Corredo fault to be a south-dipping reverse fault with a dip of about 80°. He estimated separation on the fault to range from 500 feet (152 m) at the county line, to 1500 feet (451 m) at Brown's Canyon. Evans and Miller (1978) mapped the Corredo fault as a zone of sheared and contorted shale in the Upper Cretaceous strata.

The age of the Corredo fault is difficult to determine. It may be pre-Saugus in age, as are the south-dipping faults in the area, or its parallel alignment with the Happy Camp syncline may indicate that the two structures are contemporaneous.

Joughin Fault

The Joughin fault is a north-dipping reverse fault that brings the Llajas Formation against the Modelo Formation. In the subsurface, the fault is defined by the Santa Susana Formation overlying the Llajas in the Union Simi 13 well (Sec. 22, T. 3N. R. 17W.). The fault dips 75° and has a separation of 1300 feet (396 m) in this well.

The Joughin fault offsets the Llajas Canyon anticline but does not offset fan material east of the study area.

Strathearn Fault

The Strathearn fault is a north-dipping reverse fault that joins the C.D.L.B. fault at Brea Canyon (Plate I). Surface dips on the fault range from 67° to 87°. Offset on the Strathearn fault can only be inferred since the fault is not encountered in any wells. Sespe surface dips and dip-meter data indicate about 350 feet (107 m) of separation on the fault between the Union Simi 3-36 (#219) well and the Union Simi 1-1 (#64) well (Cross Section B-B', Plate VIII). The Strathearn fault does not offset older alluvium. The map pattern suggests that the Strathearn fault terminates against the C.D.L.B. fault, which predates the Saugus Formation. If this relation is correct, then the Strathearn fault is also pre-Saugus in age.

C.D.L.B. Fault

The Canada de la Brea (C.D.L.B.) fault is a north-dipping reverse fault that dips 65° to 75° at the surface. It extends from Brea Canyon to a point south of Moorpark College, where it is concealed beneath alluvium. East of Brea Canyon, the fault trends northwest-southeast and may intersect the Simi fault west of Dry Canyon (Plate I). The C.D.L.B. fault forms the upstructure trap for the Oak Park and C.D.L.B. oil fields.

Subsurface control on the C.D.L.B. fault is based on a repeat of Sespe electric log markers in six wells. In the C.D.L.B. 15 (#131) well, evidence for the fault is based on an anomalously thick Llajas section, with the exact location of the fault being inferred from a projected surface dip (Cross Section D-D', Plate X). Separation on the C.D.L.B. fault ranges from 1050 feet (320 m) in Cross Section D-D' (Plate X) to 350 feet (107 m) in the Union Simi 1-35 (#194) well (unpublished cross section).

In the C.D.L.B. oil field, two southeast-dipping reverse faults extend to the northeast from the C.D.L.B. fault (Plate I). The more easterly fault cuts the Union C.D.L.B. 15 (#131) well and offsets Sespe electric log markers 170 feet (52 m) between this well and the Union C.D.L.B. 16 (#132) well (Cross Section D-D', Plate X). The western fault offsets the Sespe LSO-"50" marker 130 feet (40 m) between the Union C.D.L.B. 4 (#121) well and the Union C.D.L.B. 17 (#133) well (Cross Section E-E', Plate XI). These two faults may form a lateral closure for the C.D.L.B. oil field.

The offset of the Sespe electric log markers between the Union Simi 4-31 (#114) well and the Union Simi 2-31

(#112) well (unpublished cross section) indicates the presence of a north-dipping reverse fault that extends beneath the alluvium of Alamos Canyon. This fault has a separation of 170 feet (52 m) and is inferred to be a splay of the C.D.L.B. fault.

The C.D.L.B. fault does not offset older alluvium. Contours on the base of the Saugus Formation are not offset by the C.D.L.B. fault, indicating that the fault is pre-Saugus in age (Figure 8). A slight down-warping of the Saugus along an axis north of, and sub-parallel to the C.D.L.B. fault is evidence for continued deformation in the area, but not along the C.D.L.B. fault.

Canter (1974) believed that the basal Saugus contours indicate a homoclinal draping across the upthrown block of the C.D.L.B. fault, thereby implying a post-Saugus movement of about 200 feet (61 m). This interpretation is contrary to the mapped trace of the fault beneath the alluvium, as confirmed by the fault point in the Union Simi 1-35 (#194) well (Plate III; unpublished cross section).

Simi Fault

The Simi fault is a north-dipping reverse fault that trends northeast along the northern margin of the Tierra Rejada and Simi Valleys. West of the study area, the fault

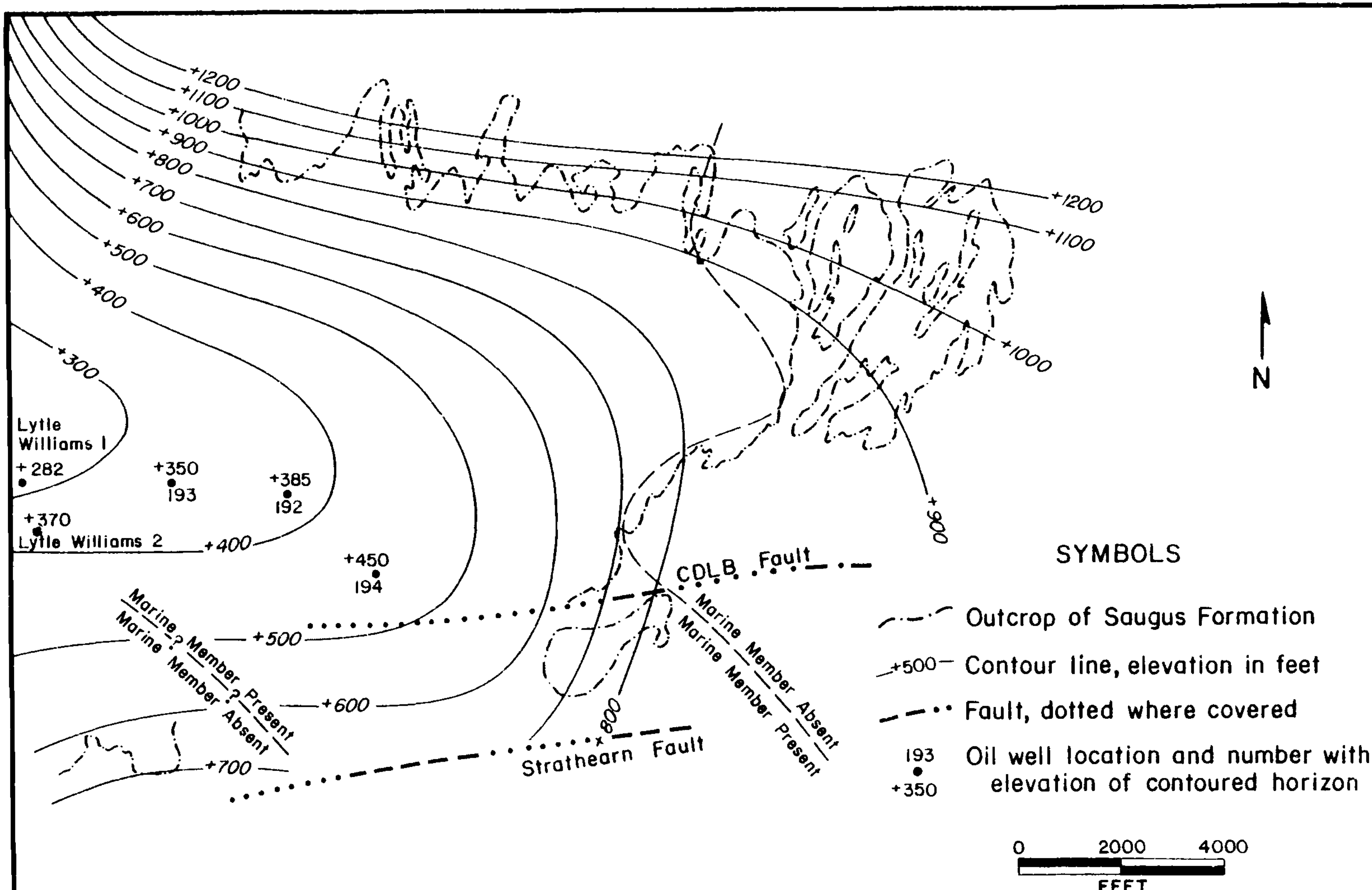

Figure 8—Structure contour map of base of Saugus Formation

extends through the Las Posas Hills and bifurcates into a northern and southern strand. Jakes (1979) reported that the Springville fault zone in the Camarillo Hills is a western continuation of the "Simi fault system".

The Simi fault dips 65^{o} north in a roadcut along State Highway 23 (Figure 9). In the subsurface, the dip of the fault varies from 63^{o} in the Carlsberg Estes 1 (#29) well (Cross Section E-E', Plate XI) to 77^{o} in the Marr Ranch 25 (#178) well (Cross Section G-G', Plate XIII).

In the subsurface, the Simi fault is defined by the Llajas Formation overlying the Sespe Formation in the Tesoro Intex-Macson-Strathearn 1 (#50) well (Cross Section B-B', Plate VIII), and by a repeat in the Sespe electric log markers and a change in the bedding dip in the Carlsberg Estes 1 (#29) well (Cross Section E-E', Plate XI).

Stratigraphic separation across the Simi fault decreases eastward from a maximum of 5300 feet (1615 m) in Cross Section A-A' (Plate VII), to 3400 feet (1036 m) in Cross Section E-E' (Plate XI), to an inferred displacement of 50 feet (15 m) in Cross Section I-I' (Plate XIV) (see discussion of proto-Simi fault); the Simi fault dies out 1000 feet (305 m) east of Oil Canyon. West of the study area, Jakes (1979) reported a projected separation of 3600 feet (1097 m) across the Simi fault in the eastern Las Posas Hills.

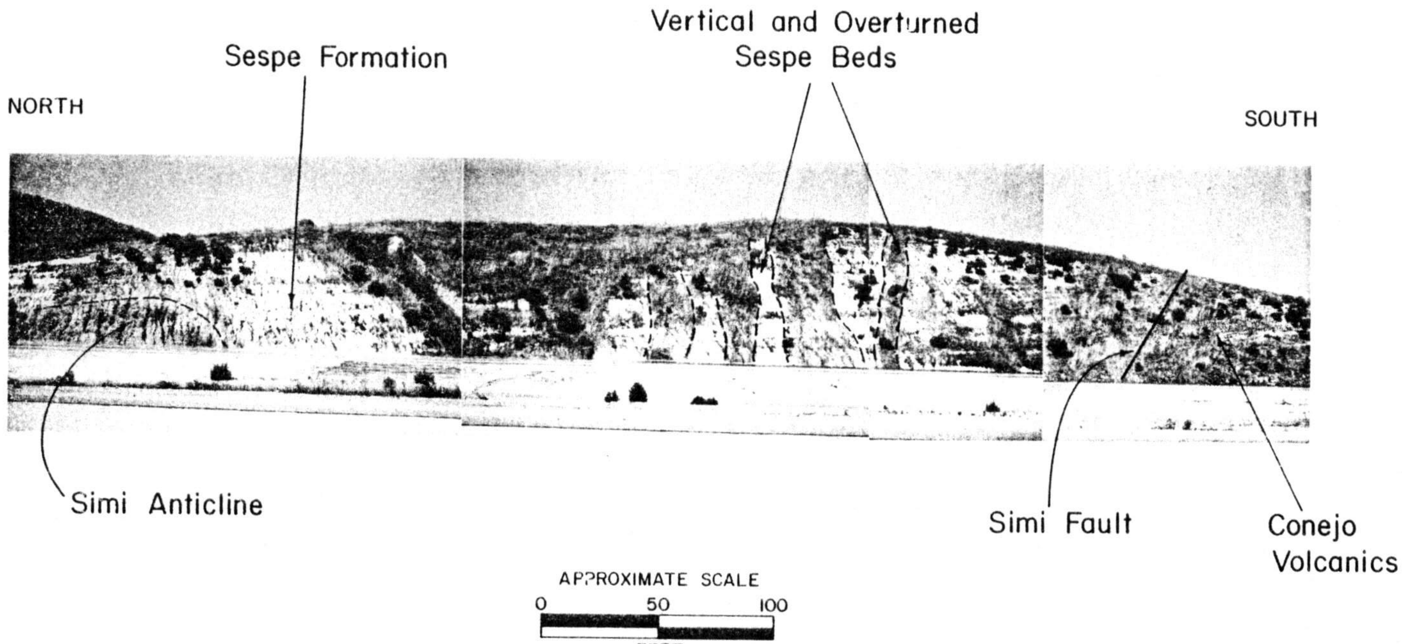

Figure 9 - Highway 23 roadcut. (after Envicom Corp., 1976)

The offset of the Conejo Volcanics in Cross Section A-A' (Plate VII) indicates a post-middle Miocene separation on the Simi fault of approximately 1450 feet (442 m). The offset of the Sespe LSO-"50" marker in this cross section implies 3850 feet (1173 m) of post-Sespe, pre-Conejo reverse separation on the fault. This post-Sespe, pre-Conejo movement on the Simi fault may coincide with the formation of the proto- Simi fault.

Plate III indicates that the Simi fault intersects the proto-Simi fault 2500 feet (762 m) east of Tapo Canyon and that the two faults merge west of this intersection (see discussion of proto-Simi fault). East of Tapo Canyon, the Simi fault truncates the Marr fault. Cross Section H-H' (Plate XIV) indicates that the south-dipping fault located between the Simi fault and the Marr fault is a splay of the Simi fault.

A trench excavation across the Simi fault northwest of Tierra Rejada Valley (T_1 on Plate I) exposes a highly fractured shear zone separating the Sespe Formation from the Conejo Volcanics. This shear zone is composed of three northeast-striking faults that dip 37° to 67° south (Figure 10). Trench T_2 (Figure 11) shows a similar south-dipping shear zone separating the Sespe from the volcanics. Observation pits dug across the contact of the Sespe Formation and a lobe of the volcanics north of the Simi fault

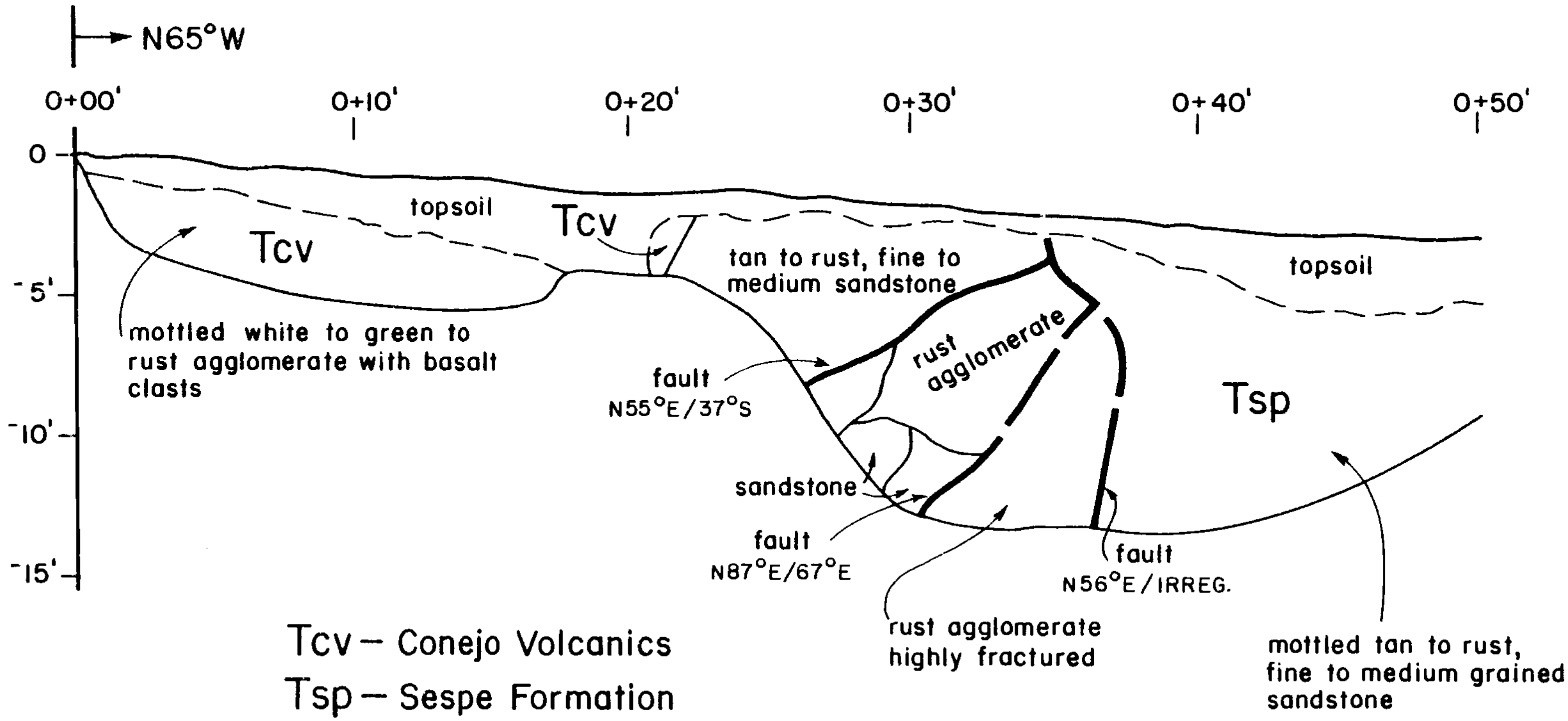

Figure 10 — Trench log T_1 (from Gorian and Associates, Inc, 1978). Location on Plate I. Southeastern 50 feet of trench shown.

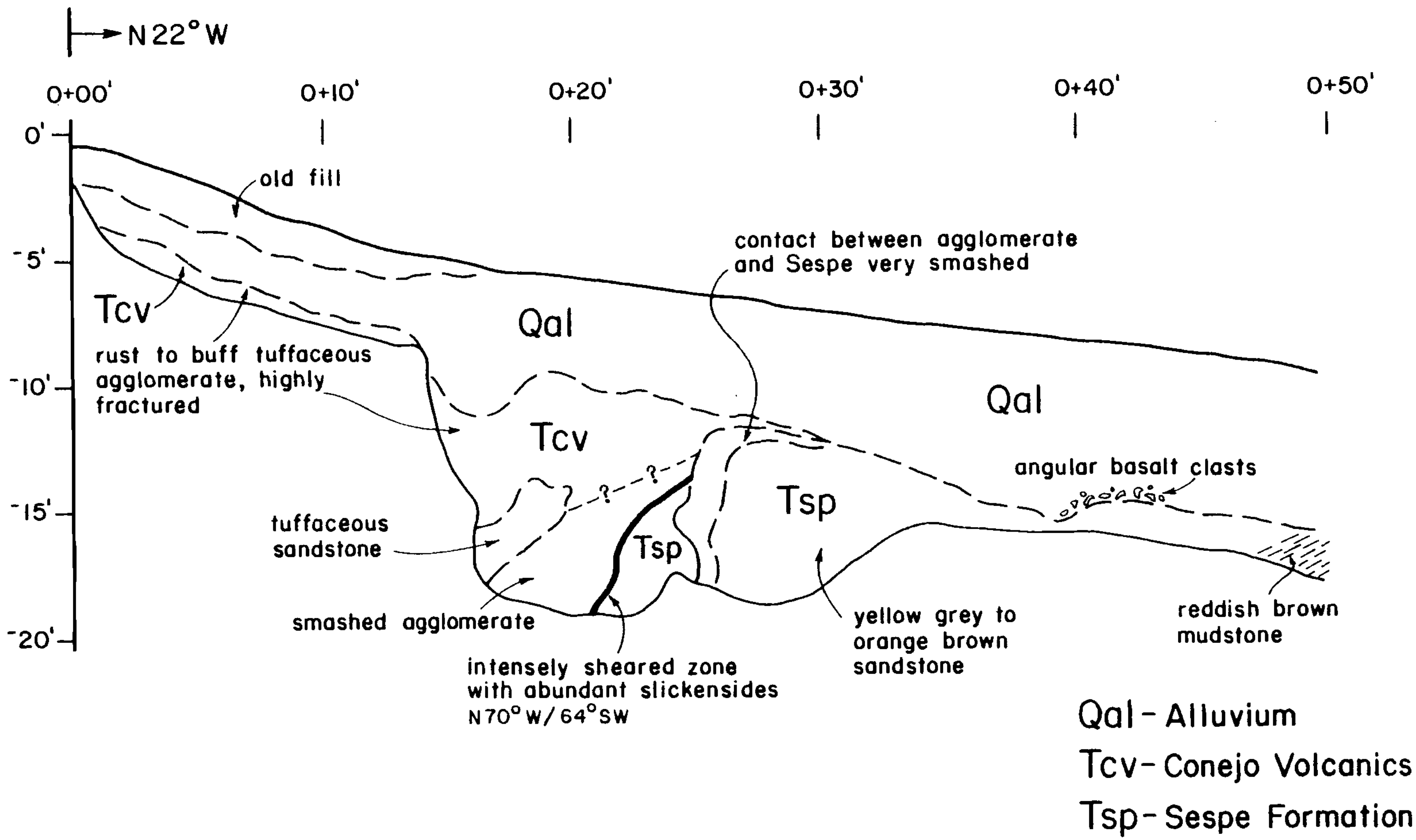

Figure 11 — Trench log T_2 (from Gorian and Associates, Inc, 1978). Location on Plate I. Southern 50 feet of trench shown.

indicate a similar south-dipping shear zone between the two formations (Gorian and Assoc., 1978). This implies that the shear zones observed in trenches T_1 and T_2 are the result of southward slumping of the Conejo Volcanics over the underlying Sespe Formation, and that the north-dipping Simi fault was not exposed in either trench.

In trench T_3 (Figure 12), the actual contact between the Sespe Formation and the Conejo Volcanics was not reached, but a number of north- and south-dipping subsidiary faults cut the Sespe. In all trenches, the overlying alluvium is not faulted.

In trench T_4 (Plate I), radiometric dating of caliche nodules from the oldest unfaulted paleosol indicate an age of 4050±100 years (Envicom Corp., 1976). In trench T_3, the unfaulted older alluvium was interpreted as being pre-Holocene in age (at least 11,000 years old) based upon the dense nature of the material (Envicom Corp., 1976). East of Tapo Canyon, however, the Simi fault has been mapped as offsetting older alluvium (California Division of Mines and Geology, 1975).

The confined groundwater flow that occurs in the Strathearn oil field area (Plate I) is the result of restricted east-to-west groundwater outflow from the Simi Valley caused by the narrowing of the alluvial outlet from the Simi Valley (Leighton and Assoc., 1972); the

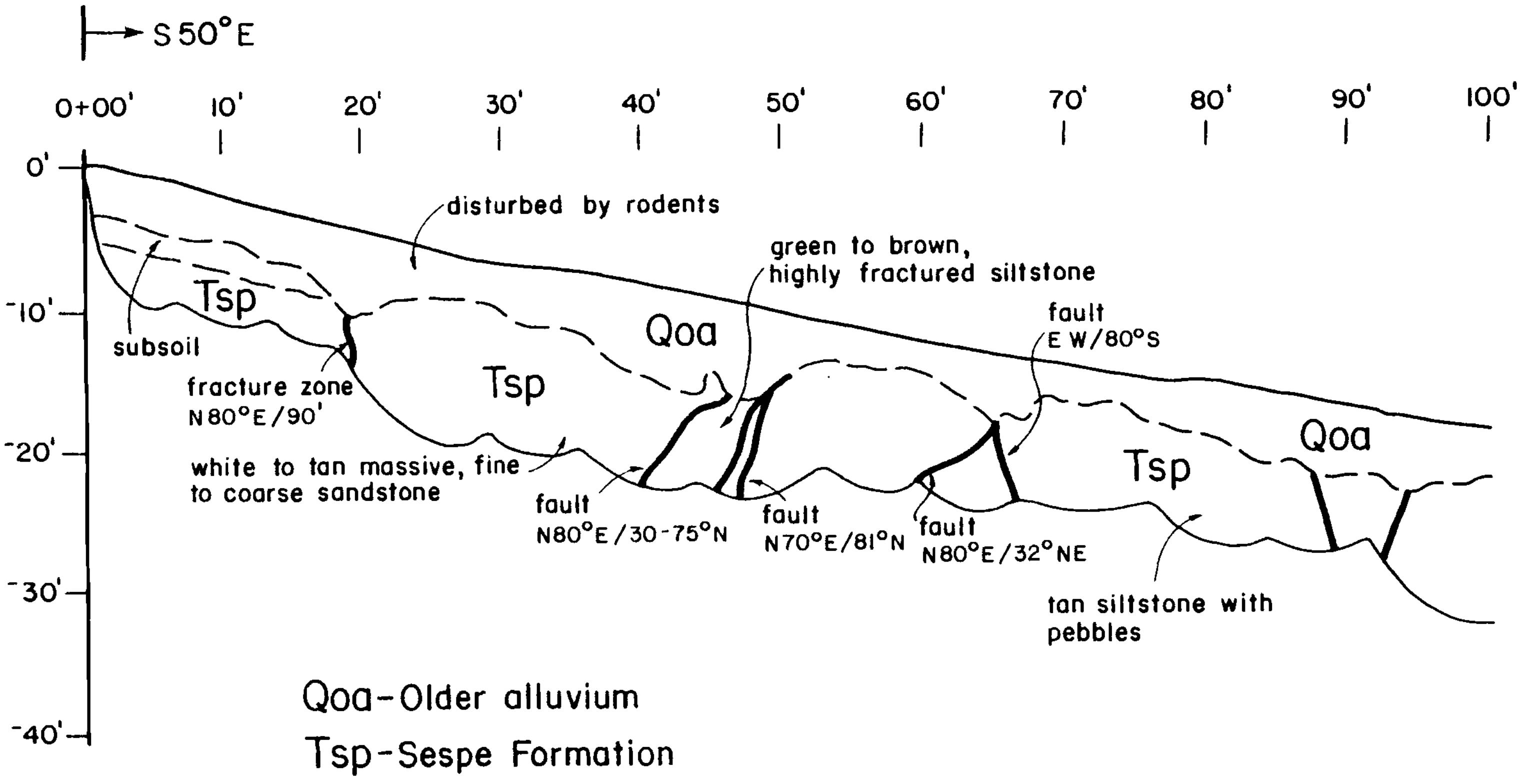

Figure 12-Trench log T_3 (from Envicom Corp., 1976).
Location on Plate I. Northern 100 feet of trench shown.

confined groundwater flow is not due to blockage by a buried scarp of the Simi fault.

Possible Lateral Offset on the Simi Fault

Truex (1976) proposed that a right-lateral offset of approximately 35 miles (53 km) occurred on a Las Posas-Simi-Frew-Soledad fault system as a result of the apparent westward movement of the Santa Monica Mountains from an original position north of the Santa Ana Mountains. As Plate I indicates, the Simi fault dies out east of the Marr Ranch and the older precursor faults (proto-Simi, Marr, Llajas, Ybarra Canyon, Brugher, and Corredo) turn to the southeast. Yeats and others (1977) showed that the Frew fault continues northwest to the Santa Susana oil field and does not connect with the Simi fault.

Based on paleomagnetic evidence, Kamerling and Luyendyk (1979) suggested that the Santa Monica Mountains and the Conejo Hills have undergone 64° to 81° of clockwise rotation. To accommodate this rotation, Luyendyk, Kamerling, and Terres (1980) proposed a left-lateral offset of approximately 20 miles (32 km) on the Simi fault.

In the Simi Valley area, there is no evidence to support large-scale lateral offset on the Simi fault. Sespe electric log correlations across the fault (Figure 13) are evidence against the large-scale lateral offsets proposed by Truex (1976) and Luyendyk, Kamerling, and

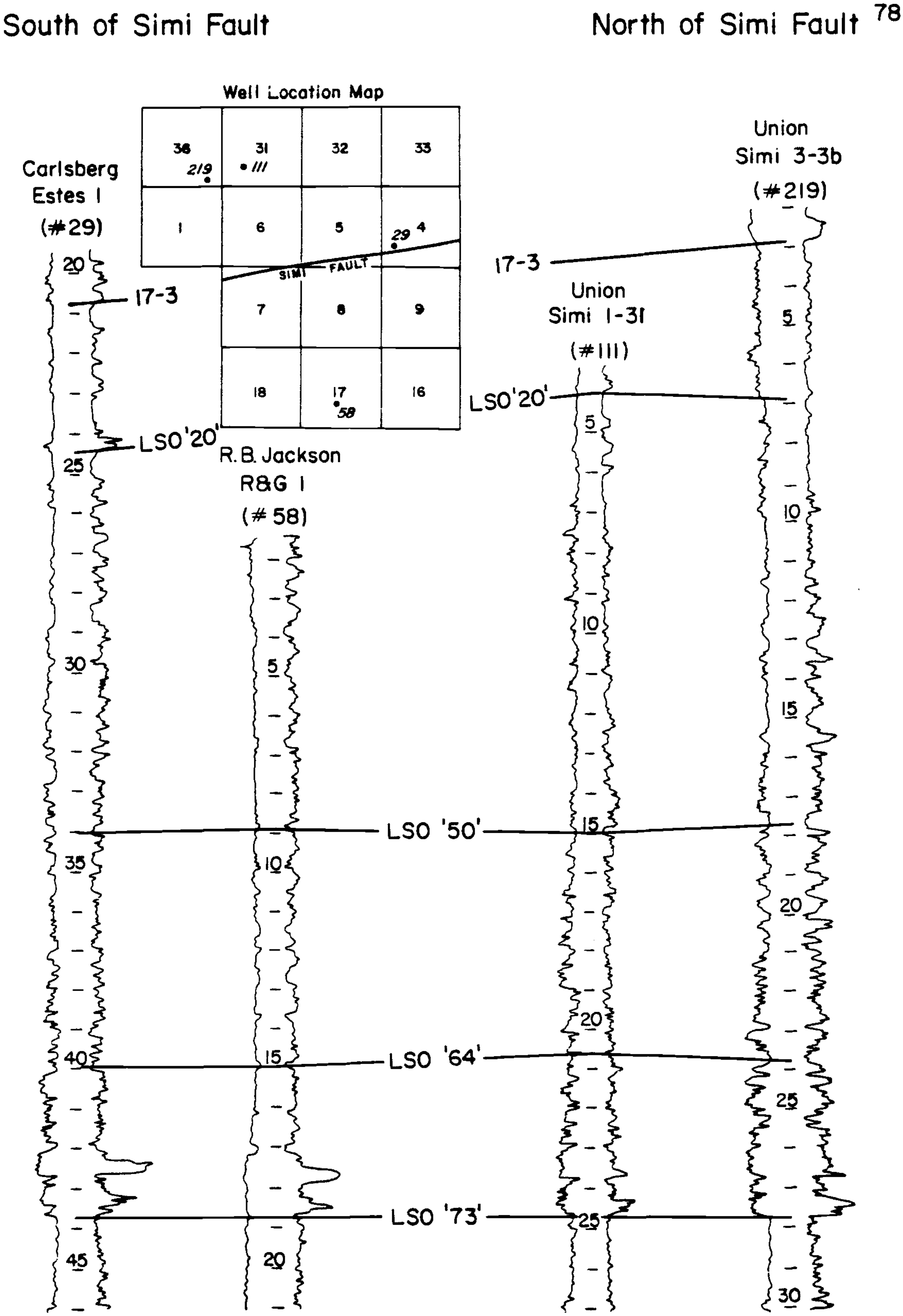

Figure 13 — Sespe correlations across Simi fault

Terres (1980). In addition, the eastward pinch out of Llajas turbidites in the subsurface on the north side of the Simi fault, between the Macson Strathearn 1 (#38) well (Cross Section C-C', Plate IX) and the Marathon Vail 1 (#69) well (unpublished cross section), do not show any large-scale lateral offset with respect to the mapped pinch out of the turbidites south of the study area (R. S. Yeats, personal commun., 1981). Further, the Llajas conglomerate on the south side of the Simi fault in Cross Sectin H-H' (Plate XIV) has similar electric log characteristics as the conglomerate on the north side of the fault in the same cross section, but is quite different from the conglomerate on the north side of the fault in Cross Section B-B' (Plate VIII) to the west. This too indicates the absence of any large-scale lateral offset to the Simi fault.

South of the Marr fault, the alluvial fan mapped as older alluvium is presently being fed by two small streams (Plate I). The extensive nature of this fan indicates that it may have been formed by a larger stream, possibly the one in Tapo Canyon. If true, this would indicate about 5000 feet (1524 m) of left-lateral offset on the Simi fault. However, a small fan at the mouth of the canyon between Dry and Brea Canyons shows no lateral offset from that canyon.

Santa Susana Pass Shear Zone

A shear zone within the Upper Cretaceous strata was mapped by Sage (1971). It extends from Santa Susana Knolls, northeast along the Santa Susana Pass to the Chatsworth area. Sage reported that the shear zone is approximately 100 feet (30 m) wide, dips to the southeast, and is marked by gouge zones, contorted bedding, truncated bedding, and diabase dikes. The shear zone does not appear to offset the contact between Cretaceous strata and the Simi Conglomerate, or the contact between the middle and upper members of the Cretaceous strata.

Normal Faults

A normal fault is located west of Alamos Canyon, between the Strathearn and C.D.L.B. faults. It trends northwest-southeast, dips 67° to the northwest, and offsets the Sespe Formation. The amount of separation on the fault is unknown.

Nett (1973) and Canter (1974) reported a northeast-southwest trending normal fault (their Airport fault) in the subsurface north of the C.D.L.B. fault. Nett (1973) believed that this fault forms the eastern trap for the Oak Park oil field. Subsurface evidence for this fault could not be confirmed.

In Cross Section F-F' (Plate XII), a normal fault is located between the Union Moorpark 1-34 (#193) well and the Union Moreland Investment 1 (#192) well. Offset on Sespe electric log markers between the two wells indicates 550 feet (168 m) of separation. The fault trends approximately north-south and dips west. It does not cut the Saugus Formation and is inferred not to cut the Vaqueros Formation.

Minor Faults

The Marr 10 fault is a reverse fault located on the north side of the Marr fault. It trends east-west, varies in dip from vertical to 85° south, and offsets the Sespe-Llajas contact about 150 to 200 feet (46 to 61 m). Nearly horizontal slickensides on the fault surface may indicate a lateral motion.

The Chivo fault trends northeast from its juncture with the Marr fault and has a vertical dip with a south-side-up separation. Separation on the Chivo fault is about 200 feet (61 m). It offsets the proto-Simi anticline and is truncated by the Marr fault (Plate I). The Chivo fault is assumed to join the proto-Simi fault at depth (Cross Section I-I', Plate XIV).

Figure 14 demonstrates the existence of a fault located beneath the alluvium of Tapo Canyon. The attitude of the fault is unknown due to the lack of well control,

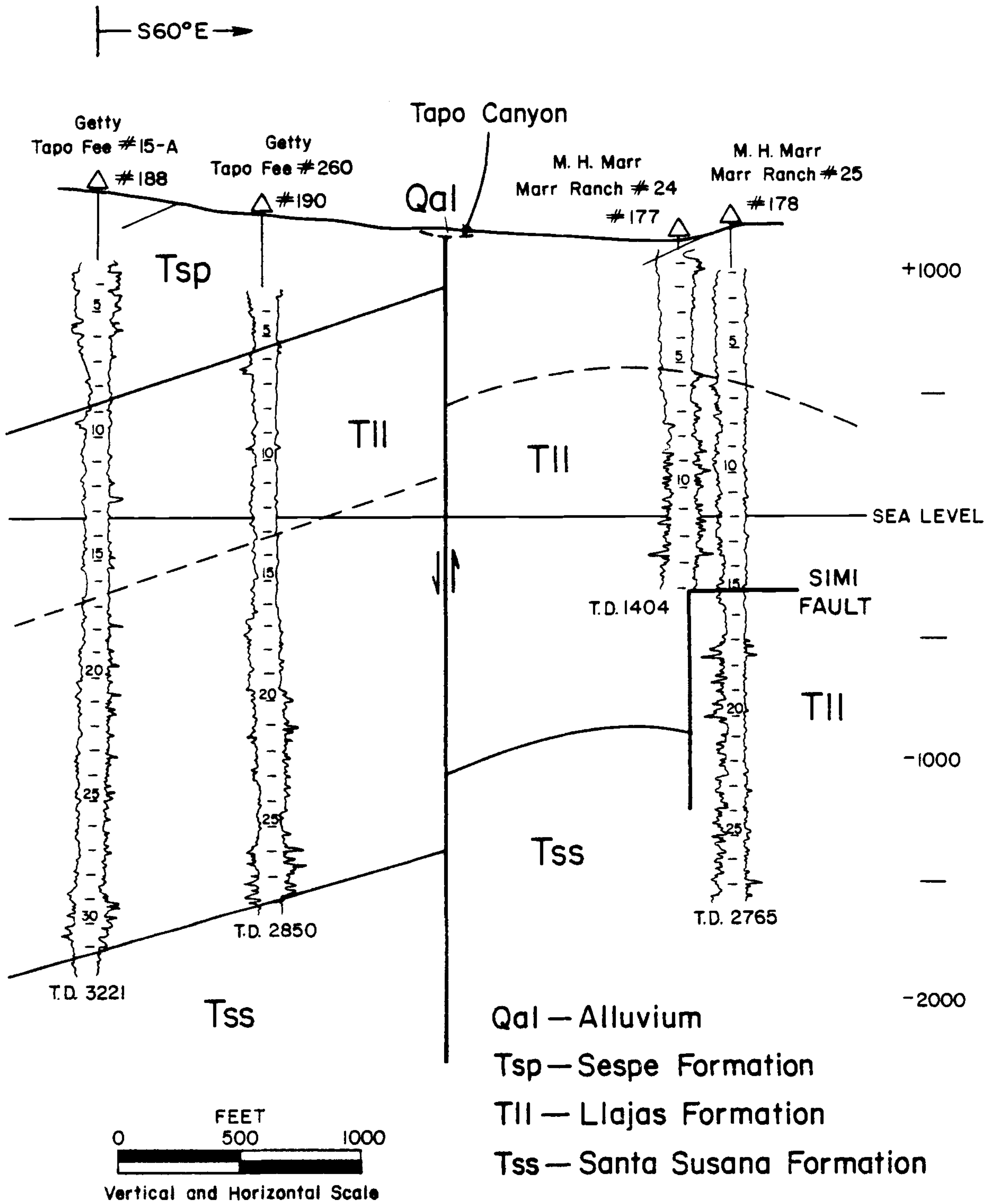

Figure 14 — Cross section showing fault beneath Tapo Canyon

but it has an east-side-up displacement. Separation across the fault in Figure 14 is about 400 feet (122 m). The offset of the Simi anticline across the fault in Plates I and V indicate that the fault may be a tear fault associated with the Simi fault.

SEISMICITY

Yerkes and Lee (1979) mapped earthquake epicenters in the western Transverse Ranges from 1970 to 1975, none of which were located on the Simi fault. Since detailed recording of seismic events began in 1932, only one earthquake has occurred within the study area: a 3.1 magnitude earthquake on November 28, 1967, located east of Tierra Rejada Valley, south of the Simi fault (latitude 34° 16.6', longitude 118° 49.2'). The focal mechanism for this event is unknown.

SEISMIC AND GROUND RUPTURE HAZARDS

Hazards associated with active or potentially active faulting can be classified as either seismic or ground rupture. Seismic hazards are caused by fault movement at depth and result in an earthquake and related ground shaking of the surrounding area. Ground rupture hazards occur when movement along a fault results in the disruption of suface materials.

In the Simi Valley area, the Simi fault is the only fault that cuts older alluvium and is therefore considered active; all other faults are considered inactive and do not present a hazard to the surrounding community. The ground rupture hazard associated with the Simi fault is difficult to evaluate since the fault cuts older alluvium east of Tapo Canyon, but does not appear to displace older alluvium in the T_3 trench. In addition, the Simi fault is inferred not to cut slump blocks of Conejo Volcanics north of Tierra Rejada Valley.

The lack of seismic activity associated with the Simi fault would tend to imply that the fault is not a seismic hazard, although a prolonged period of seismic inactivity does not preclude the possibility that a major seismic event may occur. The nature of the seismic hazard associated with the Simi fault is therefore still unresolved.

Of greater importance to the Simi Valley is the possibility that a severe earthquake in the surrounding area could result in the liquefaction of the alluvial areas with high groundwater levels. Dewatering of these high groundwater areas is a solution to this problem that has been proposed by Leighton and Associates (1972).

GEOLOGIC HISTORY

The Upper Cretaceous rocks exposed south and east of the Simi Valley were deposited in a relatively deep continental shelf basin by northwest-flowing turbidity currents (Sage, 1971; Colburn, 1973). Uplift and subsequent erosion of these rocks resulted in an irregular topography upon which a southwest-flowing alluvial fan complex developed, depositing the early Paleocene Simi Conglomerate. The reworking of the uppermost part of the Simi Conglomerate during a marine transgression resulted in the deposition of the Marine Paleocene unit (Zinsmeister, 1974).

Deposition of the siltstones of the Santa Susana Formation occurred during continued marine transgression and deepening of the sedimentary basin. Periodic influxes of coarse clastics into the basin resulted in the deposition of the Santa Susana conglomerate and the Meier Canyon and Runkle Canyon sandstone tongues. By early Eocene, a closing off of the open ocean conditions that had prevailed during the late Paleocene marked the beginning of a marine regression (Browning, 1952). This regression continued with the shallow marine deposition of the basal conglomerate of the Llajas Formation and was followed by a transgressive-regressive cycle during which the glauconitic siltstones and turbidite sandstones of the Llajas Formation were deposited (Schmidt, 1970; Howell, 1974).

By late Eocene, the regression culminated with the development of an alluvial fan and braided river system that deposited the conglomerate and sandstone of the lower Sespe Formation. Channel, point bar, and floodplain deposits of the upper Sespe Formation were deposited by a meandering river system that developed with the infilling of the Sespe basin (McCracken, 1972).

Extension in the Ventura basin followed deposition of the Sespe Formation and resulted in the formation of normal faults. Normal faulting ceased with the transgression of an early Miocene sea and the deposition of the shallow-water Vaqueros Formation (Hall and others, 1967; Canter, 1974).

The Rincon Formation described by Edwards (1971) in the Big Mountain area, accumulated in a shallow-marine to brackish-water environment on a shelf that extended from Santa Cruz Island to Oak Ridge, and southward to the Santa Monica Mountains (Edwards, 1971). Formation of the Simi anticline and the Simi fault occurred after deposition of the Rincon Formation and resulted in 3850 feet (1173 m) of reverse separation on the fault in the Tierra Rejada Valley area, prior to the deposition of the Conejo Volcanics. The eastern end of this pre-Conejo Volcanic Simi fault is inferred to be the proto-Simi fault (Figure 15).

Middle Miocene transgression over the Simi Valley-Oak Ridge area resulted in the deposition of a thin, discontinuous Topanga Formation unconformably over all underlying strata. This is in contrast to the thick, continuous deposition of the Topanga in the rapidly subsiding East Ventura basin northeast of the Simi Valley area.

Middle Miocene extension and volcanism occurred in the Santa Monica Mountains coincident with the encounter of the East Pacific Rise with the North American continent. The Conejo Volcanics were erupted subaqueously and flowed northward from their eruptive centers into a structurally controlled marine basin (Williams, 1977). Volcanic flows extended to just east of Tierra Rejada Valley, and northward over the Simi fault to the southwest flank of Big Mountain. Thick, localized accumulations of volcanics in the Camarillo and Las Posas Hills resulted in the subsidence of the Sespe Formation along south-dipping normal faults (Jakes, 1979). With continued eruption, the Miocene basin began to fill, and subsequent volcanic rocks were erupted in a subaerial environment. Sedimentary and epiclastic rocks of the Topanga Formation continued to be deposited during and after eruption of the Conejo Volcanics.

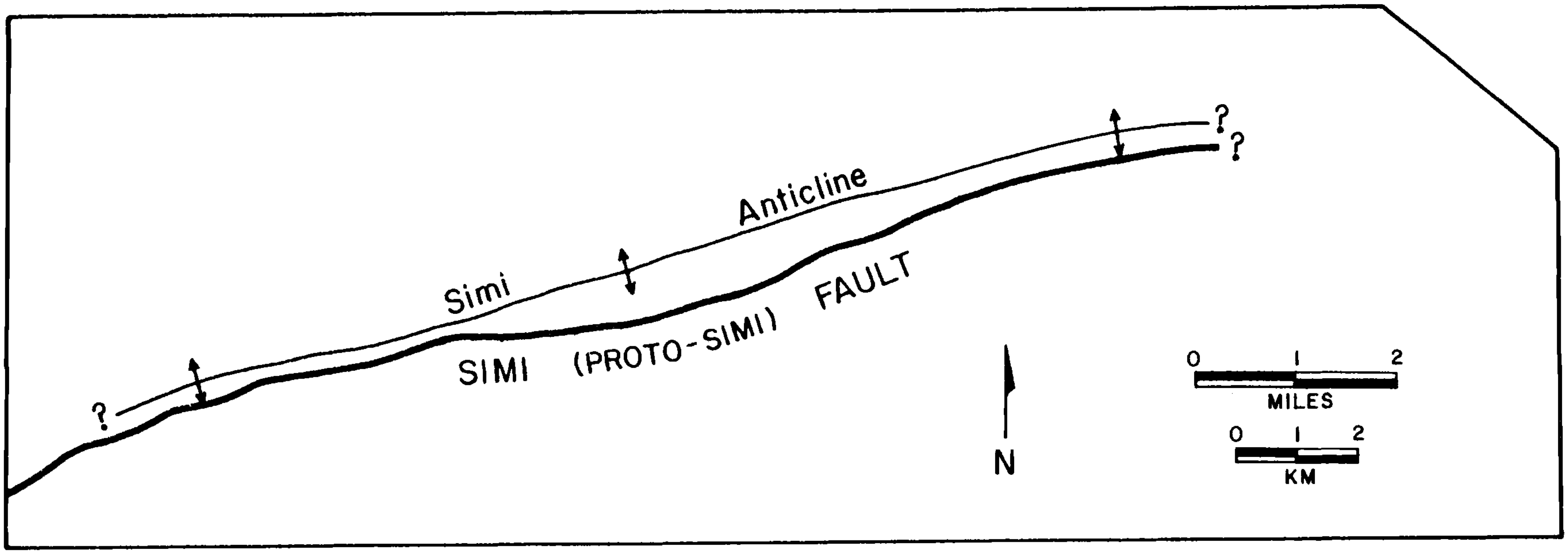

Figure 15–Post-Rincon, pre-Conejo Volcanic structures (early Miocene–middle Miocene).

Chert, siliceous shale, and turbidites of the Modelo Formation were deposited conformably on the Topanga Formation in a deep sedimentary basin northeast of the Simi Valley area. A deep-water environment also existed to the south and west of the Santa Monica Mountains and the Conejo Hills. During this period, the Simi Valley area was a northwest-sloping shelf upon which the Modelo Formation was deposited unconformably on rocks as old as Cretaceous.

Formation of the south-dipping Marr, Brugher, Llajas, Ybarra Canyon, and possibly the Corredo faults is assumed to have occurred during Pico deposition, coincident with the formation of the south-dipping Frew fault in the Aliso Canyon area. After deposition of the Pico Formation, the Frew fault was truncated by the north-dipping Roosa fault. A similar situation occurred in the Simi Valley area at this time with movement along the present trace of the Simi fault, and the resulting truncation of the south-dipping Marr fault. Formation of the north-dipping Joughin, C.D.L.B., and Strathearn faults is inferred to have occurred subsequent to Pico deposition, and to have ceased movement prior to deposition of the Saugus Formation (Figure 16).

Deposition of the shallow-marine and brackish-water basal member of the Saugus Formation followed the late

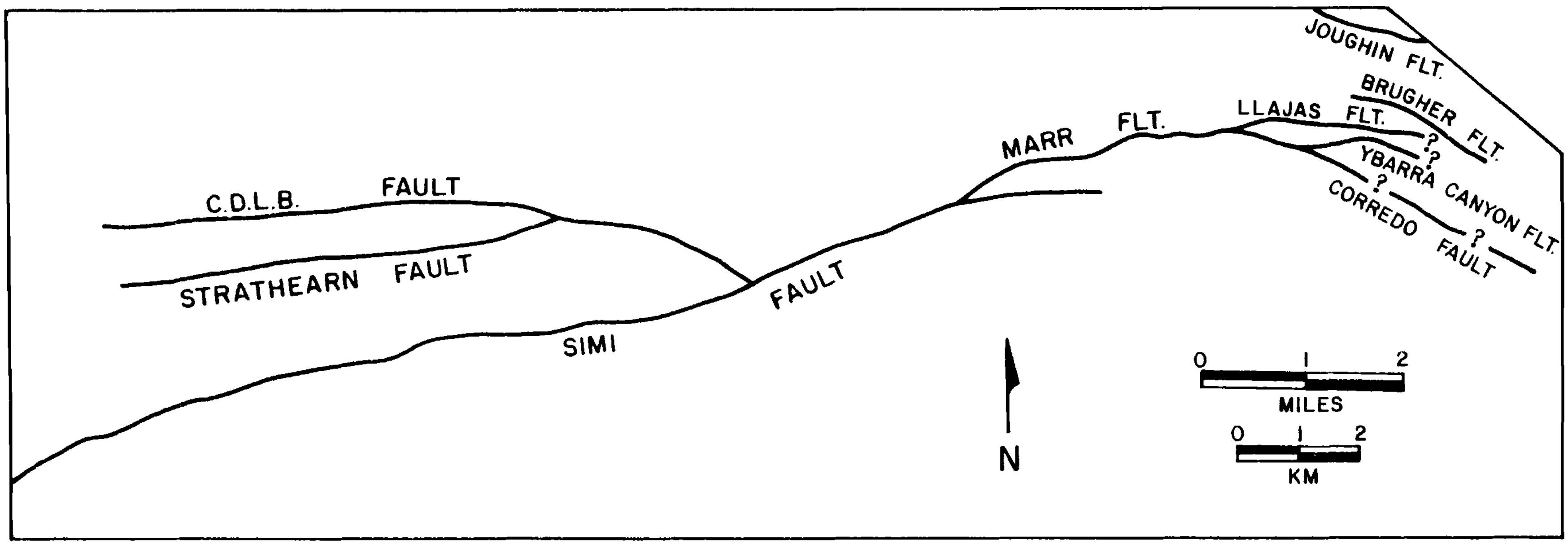

Figure 16 – Post-Modelo, pre-Saugus structures (Pliocene).

Pliocene marine regression in the Ventura basin; the remainder of the Saugus Formation accumulated under nonmarine conditions. Uplift of the Santa Susana Mountains occurred during Saugus deposition and blocked off the San Gabriel Mountains as a source terrain for Saugus detritus (Saul, 1975).

Formation of the Happy Camp syncline occurred after deposition of the Saugus Formation. The parallel alignment of the syncline with the Santa Susana fault indicates that both structures formed in response to the same northeast-southwest oriented stress. Folding of the eastern part of the Llajas and Ybarra Canyon faults may have been contemporaneous with the formation of the Happy Camp syncline, resulting in overturning of the fault planes. The offset of the marine Saugus Formation by the eastern half of the Ybarra Canyon fault may indicate that the fault was active through this time, or that the marine Saugus was offset during folding of the fault. The remainder of the south-dipping reverse faults in the area all ceased movement prior to the deposition of the Saugus Formation.

Post-Saugus movement on the Simi fault is evident in the Las Posas Hills, west of the study area (Jakes, 1979). In the Simi Valley area, the Simi fault offsets older alluvium east of Tapo Canyon, but subsidiary faults in the Sespe Formation in the T_3 trench do not offset older alluvium. In addition, slump blocks of Conejo Volcanics overlie but are not cut by the Simi fault (Figure 17).

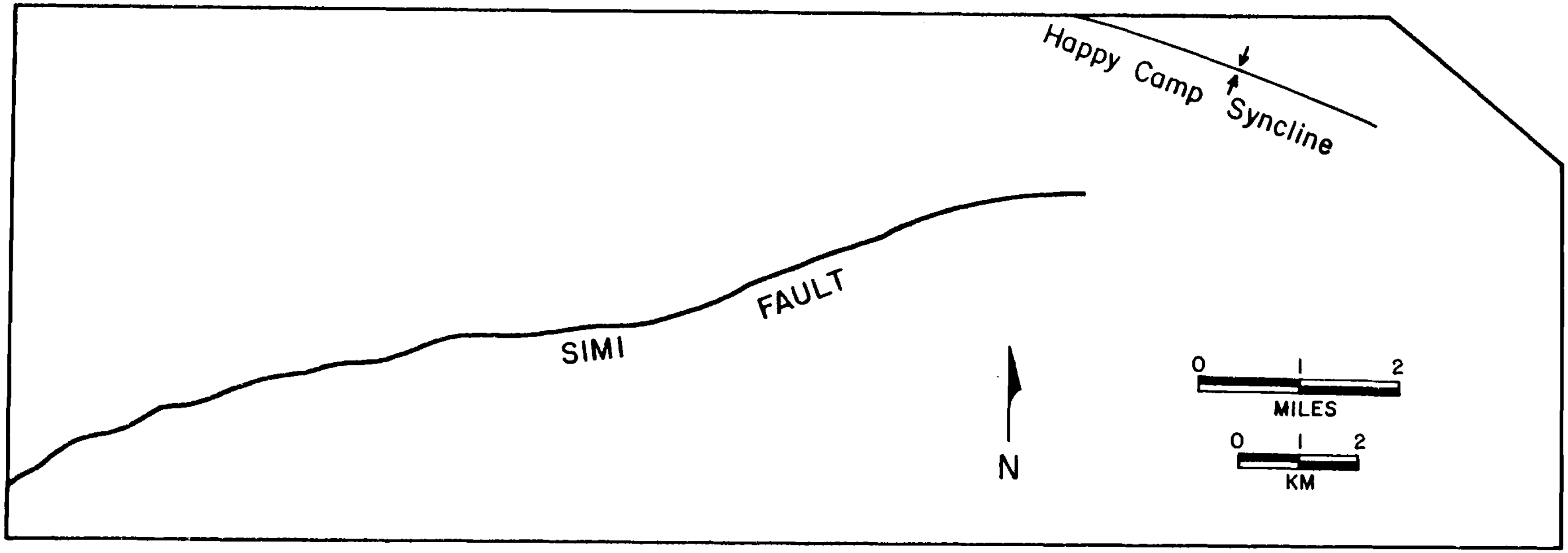

Figure 17– Post-Saugus structures.

REFERENCES CITED

Almgren, A. A., 1973, Upper Cretaceous foraminifera in southern California, in Colburn, I. P., and Fritsche, A. E., eds., p. 31-44, Cretaceous stratigraphy of the Santa Monica Mountains and Simi Hills: Pacific Section, Soc. Econ. Paleontologists and Mineralogists, Fall Fieldtrip Guidebook, October 27, 1973.

Bailey, T. L., 1947, Origin and migration of oil into Sespe redbeds: Amer. Assoc. Petroleum Geol. Bull., v. 31, p. 1913-1935.

Berggren, W. A., 1972, A Cenozoic time-scale--Some implications for regional geology and paleobiogeography: Lethaia, v. 5, p. 195-215.

Bishop, W. C., 1950, Geology of the southern flank of Santa Susana Mountains, county line to Limekiln Canyon, Los Angeles County, California: unpublished M.S. thesis, Univ. of California, Los Angeles.

Browning, J. L., 1952, Eocene foraminifera from the upper Santa Susana Shale: Univ. of California, Berkeley, unpublished M.A. thesis.

Cabeen, W. R., 1939, Geology of the Aliso and Browns Canyon area, Santa Susana Mountains, California: unpublished M.S. thesis, California Institute of Technology.

California Division of Mines and Geology, 1975, Seismic hazards of Ventura County, California: open file report 76-5 LA.

California State Water Resources Board, 1953, Ventura County investigation: Bull. no. 12, vol. II.

Canter, N., 1974, Paleogeology and paleogeography of the Big Mouintain area, Santa Susana, Moorpark, and Simi quadrangles, Ventura County, California: unpublished M.S. thesis, Ohio University, 57 p.

Carey, S. and Colburn, I. P., 1978, Late Cretaceous sedimentation in the Santa Monica Mountains, California, in Howell, D. G. and McDougall, K. A., eds., Mesozoic paleogeography of the western United States: Pacific Section, Soc. Econ. Paleontologists and Mineralogists, p. 547-558.

Clark, B. L., 1918, Meganos Group, a newly recognized division in the Eocene of California: Geol. Soc. America Bull., v. 29, p. 281-296.

Clark, B. L., and Vokes, H. E., 1936, Summary of marine Eocene sequence of western North America: Geol. Soc. America Bull., v. 47, p. 851-878.

Colburn, I. P., 1973, Stratigraphic relations of the southern California Cretaceous strata: Fall Field Trip Guidebook, Pacific Section, Soc. Econ. Paleontologists and Mineralogists, p. 45-75.

Cushman, J. A., and Leroy, L. W., 1938, A microfauna from the Vaqueros Formation, lower Miocene, Simi Valley, Ventura County, California: Jour. Paleo., v. 12, no. 2, p. 117-126.

Cushman, J., and McMasters, J., 1936, Middle Eocene foraminifera from the Llajas Formation, Ventura County, California: Jour. Paleo., v. 10, no. 6, p. 497-517.

Durham, J. W., Jahns, R., and Savage, D., 1954, Marine-non-marine relationships in the Cenozoic section California: in Jahns, R., ed., 1954, Geology of southern California: California Div. of Mines, Bull. 170, Chap. III, no. 7, p. 59-72.

Durrell, C., 1954, Geology of the Santa Monica Mountains, Los Angeles and Ventura Counties, California: map sheet 8 in Jahns, R., ed., Geology of southern California: California Div. of Mines, Bull. 170.

Edwards, L. N., 1971, Geology of the Vaqueros and Rincon Formation, Santa Barbara Embayment, Califonria: unpublished Ph.D. dissertation, Univ. of California, Santa Barbara, 240 p.

Eldridge, G. H., and Arnold, R., 1907, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U.S. Geol. Survey, Bull. 309, 266 p.

Envicom Corporation, 1976, Geological and environmental studies for EDA technical assistance grant no. 07-6-01529: unpublished report, 62 p.

Evans, J. R., and Miller, R. V., 1978, Geology of the southwestern part of the Oat Mountain quadrangle, Los Angeles County, California: Calif. Div. Mines Geol., Map Sheet 33.

Fantozzi, J. H., 1955, The stratigraphy and biostratigraphy of a protion of the Simi Hills on the south side of the Simi Valley, Ventura County, California: unpublished M.S. thesis, Univ. of California, Los Angeles.

Gorian and Associates, Inc., 1978, Geotechnical and soils engineering investigation, tentative tract 2865, Moorpark Road and Peach Hill Road, Moorpark area, Ventura County, California: unpublished report, work order 863-1-10.

Grier, A. W., 1953, Lower Tertiary Foraminifera from the Simi Valley, California: unpublished M.A. thesis, Univ. of California, Berkeley.

Hall, E. A., Saunders, J. M., and Durrie, J. H., 1967, Geology of the Big Mountain oil field and nearby areas: Field Trip Guidebook, Amer. Assoc. Petroleum Geol., Pacific Section, June 2, 1967.

Hamlin, H., 1904, Water resources of the Salinas Valley: U.S. Geol. Survey Water Supply Paper 89.

Hershey, O. H., 1902, Some Tertiary formations of southern California: American Geologist, v. 29, p. 349-372.

Hetherington, G. E., 1957, Geology of the South Tapo Canyon area, Ventura County, California: unpublished M.A. thesis, Univ. of California, Los Angeles.

Howell, D. G., 1974, Middle Eocene paleogeography of southern California: unpublished Ph.D. dissertation, Univ. of California, Santa Barbara.

Jakes, M. C., 1979, Surface and subsurface geology of the Camarillo and Las Posas Hills area, Ventura County, California: unpublished M.S. thesis, Oregon State University, 105 p.

Kamerling, M. J. and Luyendyk, B. P., 1979, Tectonic rotations of the Santa Monica Mountains region, western Transverse Ranges, California, suggested by paleomagnetic vectors: Geol. Soc. America Bull., Part I, v. 90, p. 331-337.

Kew, W. S., 1919, Structure and oil resources of the Simi Valley, southern California: U.S. Geol. Survey Bull. 691-M.

Kew, W. S. W., 1924, Geology and oil resources of Los Angeles and Ventura Counties, California: U.S. Geol. Survey, Bull. 753, 202 p.

Laiming, B., 1939, Some foraminiferal correlations in the Eocene of San Joaquin Valley, California: Pacific Sci. Cong., 6th Proc., v. 2, p. 535-568.

Lant, K. J., 1977, Structure of the Aliso Canyon area, eastern Ventura basin, California: Ohio University, unpublished M.S. thesis.

Leighton, F. Beach, and Associates, 1972, Geologic-seismic report for the City of Simi Valley, Simi Valley, California: unpublished report, no. 1298.

Levorsen, R. I., 1947, Geology of the Las Llajas Canyon area: Univ. of California, Los Angeles, unpublished M.A. thesis.

Lewis, W. D., 1940, The geology of the upper Las Llajas Canyon area, Santa Susana Mountains, California: unpublished M.S. thesis, California Institute of Technology, 75 p.

Luyendyk, B. P., Kamerling, M. J., and Terres, R., 1980, Geomertric model for Neogene crustal rotations in southern California: Geol. Soc. America Bull., Part I, v. 91, p. 211-217.

McCracken, W. A., 1972, Paleocurrents and petrology of Sespe sandstones and conglomerates, Ventura basin, California: unpublished Ph.D. dissertation, Stanford University, 192 p.

McMasters, J. H., 1933, Eocene Llajas Formation, Ventura County, California (abstr.): Geol. Soc. America Bull., v. 44, pt. 1, p. 271-281.

Martini, E., 1971, Standard Tertiary and Quaternary calcareous nannoplankton zonation, in Farinacci, A., ed., Proceedings of Second Planktonic Conference: Roma, E. Tecnoscienza, p. 739-785.

Mallory, V. S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Am. Assoc. Petroleum Geol., 416 p.

Merriam, C. W., 1941, Fossil Turritellas from the Pacific Coast Region of North America: Univ. Calif. Publ., Bull. Dept. Geol. Sci., v. 26, 214 p.

Merriam, C. W., and Turner, F. E., 1937, The Capay middle Eocene of northern California: Univ. Calif. Publ., Bull. Dept. Geol. Sci., v. 24, no. 6, p. 91-114.

Nelson, R. N., 1925, A contribution to the paleontology of the Martinez Eocene of California: Univ. Calif. Publ., Bull. Dept. Geol. Sci., p. 397-466.

Nett, A. R., 1973, A quantitative analysis of production in the Oak Park field, Moorpark, California, using sedimentological and structural criteria: unpublished M.S. thesis, University of Southern California.

Oakeshott, G. B., 1958, Geology and mineral deposits of San Fernando quadrangle, Los Angeles County, California: Calif. Div. Mines Bull. 172, 147 p.

Poore, R. S., 1976, Microfossil correlation of California lower Tertiary sections: a comparison: U.S. Geol. Survey Professional Paper 743-F, 8 p.

Poore, R. S., 1980, Age and correlation of California Paleogene benthic foraminiferal stages: U.S. Geol. Survey Professional Paper 1162-C, 8 p.

Popenoe, W. P., 1973, Southern California Cretaceous Formations and faunas with special reference to the Simi Hills and the Santa Monica Mountains, in Colburn, I. P., and Fritsche, A. E., eds., p. 15-30, Cretaceous stratigraphy of the Santa Monica Mountains and Simi Hills: Pacific Section, Soc. Econ. Paleontologists and Mineralogists, Fall Fieldtrip Guidebook, October 27, 1973.

Pressler, E., 1929, The Fernando Group in the Las Posas-South Mountain district, Ventura County, California: Univ. of Calif. Publ., Bull. Dept. Geol. Sci., v. 18, no. 13, p. 325-345.

Ricketts, E. W., and Whaley, K. R., 1975, Structure and stratigraphy of the Oak Ridge-Santa Susana fault intersection, Ventura basin, California: unpublished M.S. thesis, Ohio University, 81 p.

Sage, O. G., 1971, Geology of the eastern portion of the "Chico" Formation, Simi Hills, California: Univ. of California, Santa Barbara, unpublished M.A. thesis.

Sage, O. G., Jr., 1973, Paleocene geography of California: unpublished Ph.D. dissertation, Univ. of California, Santa Barbara.

Saul, R. B., 1975, Geology of the southeast slope of the Santa Susana Mountains and geologic effects of the San Fernando earthquake: California Div. Mines and Geology Bull. 196, p. 187-194.

Savage, D., and Downs, T., 1954, Cenozoic land life of southern California: in Jahns, R., ed., 1954, Geology of southern California: California Div. of Mines, Bull. 170, Chap. III, no. 6, p. 43-58.

Schenck, H. G., 1931, Cepahlopods of the genus Aturia from western North America: California Univ. Pubs., Dept. Geol. Bull., v. 19, no. 19, p. 436-491.

Schmidt, R. R., 1970, Planktonic foraminifera from the Lower Tertiary of California: unpublished Ph.D. dissertation, Univ. of California, Los Angeles.

Shields, K. E., 1977, Structure of the northwestern margin of the San Fernando Valley, Los Angeles County, California: Ohio University, unpublished M.S. thesis.

Squires, R. L., 1977, Terebratulid death assemblage, Plio-Pleistocene of Browns Canyon, Santa Susana Mountains, California (abstr.): Geol. Soc. America Abs. with Programs, v. 9, p. 597.

Squires, R. L., 1979, New macrofossil occurrences, Stewart bed, middle Eocene Llajas Formation, Llajas Canyon, Santa Susana Mountains, California (abstr.): Geol. Soc. America Abs. with Programs, v. 11, p. 129.

Stipp, T. F., 1943, Simi oil fields: Calif. Div. of Mines Bull. 118, p. 417-423.

Stock, C., 1932, An upper Oligocene mammalian fauna from southern California: Proc. Nat. Acad. Sci., v. 18, p. 550-554.

Susuki, T., 1952, Stratigraphic paleontology of the type section of the Topanga Formation, Santa Monica Mountains, California: Geol. Soc. America Bull., v. 63, pt 2. p. 1345.

Taliaferro, N., 1924, The oil fields of Ventura County, California: Amer. Assoc. Petroleum Geol. Bull., v. 8, sect. I, p. 789-810.

Truex, J., 1976, Santa Monica and Santa Ana Mountains - relation to Oligocene Santa Barbara basin: Amer. Assoc. Petroleum Geol. Bull., v. 60, no. 1, p. 65-86.

Turner, D. L., and Campbell, R. H., 1979, Age of the Conejo Volcanics, in Yerkes, R. F., and Campbell, R. H., Stratigraphic nomenclature of the central Santa Monica Mountains, Los Angeles County, California: U.S. Geol. Survey Bull., no. 1457-E, 31 p.

U.S. Department of the Interior, Bureau of Reclamation, 1957, Calleguas project: engineering geology report.

Van Camp, Q. W., 1959, Geology of the Big Mountain area, Santa Susana and Simi quadrangles, California: unpublished M.S. thesis, Univ. of California, Los Angeles.

Waring, C. A., 1917, Stratigraphic and faunal relations of the Martinez to Chico and Tejon of southern California: Calif. Acad. Sci., Series 4, Proc., v, VII, no. 4. p. 41-124.

Watts, N., 1897, Oil and gas yielding formations of Los Angeles, Ventura, and Santa Barbara Counties, California: California Div. Min. Bur. Bull. 14, p. 22-28.

Williams, R., 1977, Miocene volcanism in the central Conejo Hills, Ventura County, California: unpublished M.S. thesis, Univ. of California, Santa Barbara.

Wilson, R. W., 1947, Rodents and lagomorphs of the upper Sespe: Carnegie Inst. Wash., Pub. no. 584, p. 51-65.

Winterer, E. L., and Durham, D. L., 1954, Geology of a part of the eastern Ventura basin, Los Angeles County, California: Calif. Div. Mines Bull. 170, Map Sheet 5.

Yeats, R. S., 1979, Stratigraphy and paleogeography of the Santa Susana fault zone, Transverse Ranges, California, in Armentrout, J. M., Cole, M. R., and Terbest, H., eds., Cenozoic paleogeographic of the western United States: Pacific Section, Soc. Econ. Paleontologists and Mineralogists, p. 191-204.

Yeats, R. S., Butler, M. L., and Schlueter, J. C., 1977, Geology of the central Santa Susana fault area, Ventura County and Los Angeles Counties, California U.S. Geol. Survey Tech. Report, no. 14-08-0001-15 886, 29 p.

Yerkes, R. F., and Campbell, R. H., 1979, Stratigraphic nomenclature of the central Santa Monica Mountains, Los Angeles County, California: U.S. Geol. Survey Bull., no. 145-E, 31 p.

Yerkes, R., and Lee, W., 1979, Late Quaternary deformation in the western Transverse Ranges, California: U.S. Geol. Survey Circ. 799-A,B, p. 27-37.

Zinsmeister, W. J., 1974, Paleocene biostratigraphy of the Simi Hills, Ventura County, California: unpublished Ph.D. dissertation, Univ. of California, Riverside.

APPENDIX

APPENDIX

Wells Utilized in Study

Key to Abbreviations Used in Appendix

TD	Total depth
O.H.	Original hole
Rd.	Redrill
GL	Ground level
DF	Drilling floor
RT	Rotary table
KB	Kelly bushing

Well Number	Location	Well Name	Elevation	Measured TD
1	Sec. 6 T.2N. R.16W.	Willard Oil Co. Sweet #1		2800 ft.
2	Sec. 1 T.2N. R.17W.	Morgan and Harris Dandy #1	1324 RT	267 ft
3	Sec. 5 T.2N. R.17W.	Germanina Trucano Trucano #1	1070 GL	1000 ft
4		Pamoan Oil Co. Flannagan #2	1320 GL	2725 ft
5		Alexander Drilling Co. #1	1280 GL	1724 ft
6		Crinklaw, Smith, and Larson Flannagan #1	1250 GL	----
7		A. J. Mead #1	1050 GL	1254 ft
8	Sec. 6 T.2N. R.17W.	Pamoan Oil Co. Hot Rod Flannagan #1	1089 RT	3236 ft
9		Funk and Loomis #2		453 ft
10		E. F. Stella Button #1-A	1000 DF	1119 ft
11		Simco Inc. #1	960 GL	887 ft
12		Santa Susana Leasehold #1	1000 DF	545 ft
13		S.S. Syndicate #1	1000 GL	1000 ft
14		S.S. Syndicate #2	1000 DF	1155 ft
15		E. A. Parkford #1	950 GL	542 ft
16		N. D. Dakis #1	1065 DF	----
17		E. A. Parkford #2	950 GL	317 ft
18		American Drilling Co. #10-A	935 DF	898 ft
19	Sec. 7 T.2N. R.17W.	C. A. Palmer Brandies #1	1191 GL	2489 ft
20	Sec. 8 T.2N. R.17W.	Pomoc Oil Co. #1	900 DF	565 ft
21		Dawson Oil Co. #1	1100 GL	1950 ft
22	Sec. 14 T.2N. R.17W.	W. R. Mack Lassen #1	1100 GL	1207 ft
23	Sec. 1 T.2N. R.18W.	Jesse C. Barnes Ricoute #1	1010 GL	771 ft
24		J. C. Barnes Didio-Jeanie #1	995 GL	600 ft
25		Bartlow-Hetman Oil Dev. Co. #2	1038 GL	850 ft
26		Bartlow-Hetman Oil Dev. Co. #4	1057 KB	600 ft
27		Simi Oil and Refining Co. #1	1000 GL	2798 ft
28	Sec. 8 T.2N. R.18W.	James S. Hull Hull #1	950 DF	1717 ft
29	Sec. 4 T.2N. R.18W.	Carlsberg Pet. Corp. Estes #1	927 KB	5651 ft
30		Carlsberg Pet. Corp. Lagomarsino E1	851 KB	2864 ft
31		G. L. Dobson Simi #1	889 RT	1206 ft
32	Sec. 5 T.2N. R.18W.	Dabney and Roberts #11	960 GL	2680 ft
33		Great Basins Pet. Co.	823 KB	4347 ft

Well Number	Location	Well Name	Elevation	Measured TD
34	Sec. 5 T.2N. R.18W.	E. A. Parkford #1	1000 DF	4003 ft
35	Sec. 6 T.2N. R.18W.	Hidalgo Oil Co. #1	860 DF	2509 ft
36		W. W. Powers #1		2091 ft
37		Shell Oil Co. Strathearn #1	807 DF	5290 ft
38		Macson Oil Co. Strathearn #1	721 KB	2828 ft
39		Macson Oil Co. Strathearn #2	710 KB	750 ft
40		Macson Oil Co. Strathearn #3	709 KB	500 ft
41		Macson Oil Co. Strathearn #4	712 KB	701 ft
42		R&R Oil Co. Strathearn #5	700 GL	940 ft
43		R&R Oil Co. Strathearn #6	704 KB	450 ft
44		R&R Oil Co. Strathearn #7	700 KB	390 ft
45		R&R Oil Co. Strathearn #8	812 KB	542 ft
46		R&R Oil Co. Strathearn #9	803 KB	738 ft
47		R&R Oil Co. Strathearn #10	690 KB	650 ft
48		Hancock Oil Co. Strathearn-Coleman #16	675 KB	3466 ft
49		Gulf Oil Co. Strathearn #47	618 KB	1450 ft
50	Sec. 7 T.2N. R.18W.	Tesoro Pet. Corp. Intex-Macson-Strathearn #1	769 KB	4615 ft
51		R&R Oil Co. Strathearn #11	704 KB	1258 ft
52	Sec. 11 T.2N. R.18W.	Carillo Exploration Co. Wickhorst #1	975 GL	3789 ft
53	Sec. 12 T.2N. R.18W.	Paloma Oil Co. Paloma-Marr #1	972 DF	2812 ft
54	Sec. 14 T.2N. R.18W.	Regent Oil Co. Runkle #1	960 GL	3246 ft
55		Newell and Lattner Newell-Lattner #1	987 DF	2303 ft
56		Simian Oil Co. Simian #1	989 KB	1178 ft
57		Webb Oil Co. Runkle #1	1180 GL	1445 ft
58	Sec. 17 T.2N. R.18W.	R. B. Jackson R.&G. #1	770 KB	3936 ft
59		Robert Cannel Cannell #1	790 GL	1201 ft
60		C. M. Levesque Robertson #1	800 GL	2315 ft
61	Sec. 18 T.2N. R.18W.	Henry C. McCoy #1	900 GL	1035 ft
62	Sec. 1 T. 2N. R.19W.	National Exploration Co. Binns #1	645 DF	3027 ft
63		Gulf Oil Corp. Binns #67	690 KB	3626 ft
64		Union Oil Co. Simi #1-1	747 RT	3100 ft
65	Sec. 2 T.2N. R.19W.	A. R. Porter Smith #1	650 GL	845 ft

Well Number	Location	Well Name	Elevation	Measured TD
66	Sec. 3 T.2N. R.19W.	A. R. Studley Studley-Birnbaum #1	614 KB	1000 ft
67	Sec. 10 T.2N. R.19W.	Charles C. Townsend Brinkop #1S	638 RT	480 ft
68	Sec. 10 T.2N. R.19W.	Charles C. Townsend Brinkop #2S	641 RT	407 ft
69		Marathon Oil Co. Vail #1	864 RT	5714 ft
70		San Marino Pet. Co. #1	600 GL	1921 ft
71	Sec. 11 T.2N. R.19W.	Mobil Oil Corp. Smith #71-A	918 KB	4800 ft
72	Sec. 12 T.2N. R.19W.	Frontier Oil co. Strathearn-Kyle #1	785 GL	3059 ft
73		H. S. Cook Bowman #1	858 KB	3540 ft
75		Henry R. Dabney Schroeder #1	785 DF	2176 ft
76	Sec. 22 T.3N. R.17W.	Union Oil Co. Las Llajas Core Hole #1	1730 DF	3317 ft
78		Union Oil Co. Las Llajas #5	1930 DF	1034 ft
79		Union Oil Co. Las Llajas #7	1950 DF	970 ft
80		Union Oil Co. Las Llajas #8	1961 DF	1253 ft
81		Union Oil Co. Las Llajas #9	2113 KB	4572 ft
82	Sec. 25 T.3N. R.17W.	Getty Oil Co. Joughin #1	2292 DF	6775 ft
84		Russell Oil Co. #1	2200 DF	4130 ft
85		Russell Oil Co. #2	2520 DF	2303 ft
86	Sec. 28 T.3N. R.17W.	Union Oil Co. Simi #24	1449 RT	5177 ft
87	Sec. 29 T.3N. R.17W.	M. H. Marr Marr Ranch #27	1918 KB	6936 ft
88		M. H. Marr Marr Ranch #103	1870 GL	1550 ft
89		Santa Susana Oil Co. #1	1870 DF	1550 ft
90	Sec. 30 T.3N. R.17 W.	M. H. Marr Marr Ranch #A-1	1247 RT	5307 ft
91		M. H. Marr Marr Ranch #11		746 ft
92		M. H. Marr Marr Ranch #12	1175 GL	420 ft
93		M. H. Marr Marr Ranch #13		1500 ft
94		M. H. Marr Marr Ranch #20	1649 GL	5346 ft
95		M. H. Marr Marr Ranch #21	1805 GL	2620 ft
96	Sec. 31 T.3N. R.17W.	M. H. Marr Marr Ranch #17	2472 KB	2664 ft
97		M. H. Marr Marr Ranch #18	1427 GL	1620 ft
98		M. H. Marr Marr Ranch #19	1430 KB	4951 ft
99		M. H. Marr Marr Ranch #22	1594 GL	2490 ft
100		Northridge Oil Co. Simco #1	1155 KB	3048 ft
101		Northridge Oil Co. Simco #2	978 KB	1220 ft

Well Number	Location	Well Name	Elevation	Measured TD
102	Sec. 31 T.3N. R.17W.	Shell Oil Co. Marr #1	1201 DF	3922 ft
103		American Drilling Co. #11-A	1000 DF	534 ft
104		Santa Susana Oil Co. #1	1320 GL	1505 ft
105		Santa Susana Oil Co. #1	1332 DF	1620 ft
106	Sec. 32 T.3N. R.17W.	M. H. Marr Marr Ranch #16	1774 KB	3789 ft
107		K. C. Oil Co. #1	1475 GL	1694 ft
108	Sec. 25 T.3N. R.18W.	Husky Oil Co. Getty Tapo Ranch #1	1326 KB	3799 ft
109	Sec. 29 T.3N. R.18W.	Atlantic Richfield Co. Tapo Fee #B-1	1037 GL	1970 ft
110	Sec. 30 T.3N. R.18W.	Union Oil Co. Simi #1-30	1166 RT	3650 ft
111	Sec. 31 T.3N. R.18W.	Union Oil Co. Simi #1-31	796 RT	3345 ft
112		Union Oil Co. Simi #2-31	961 RT	3600 ft
113		Union Oil Co. Simi #3-31	860 RT	4000 ft
114		Union Oil Co. Simi #4-31	874 RT	4000 ft
115		Union Oil Co. Simi #5-31	850 RT	----
116		Union Oil Co. Simi #6-31	908 RT	2922 ft
117	Sec. 32 T.3N. R.18W.	Union Oil Co. Simi #7-32	930 RT	2500 ft
118		Union Oil Co. C.D.L.B. Core Hole #1	901 GL	1065 ft
119		Union Oil Co. C.C.L.B. Core Hole #2	1027 DF	1770 ft
120		Union Oil Co. C.D.L.B. #3	924 DF	1870 ft
121		Union Oil Co. C.D.L.B. #4	991 DF	2867 ft
122		Union OIl Co. C.D.L.B. #5	935 GL	1751 ft
123		Union Oil Co. C.D.L.B. #6	990 GL	1150 ft
124		Union Oil Co. C.D.L.B. #7	1050 GL	1604 ft
125		Union Oil Co. C.D.L.B. #8	1058 GL	2030 ft
126		Union OIl Co. C.D.L.B. #9	1150 RT	2100 ft
127		Union Oil Co. C.D.L.B. #11	1204 DF	1978 ft
128		Union Oil Co. C.D.L.B. #12	1130 RT	2063 ft
129		Union Oil Co. C.D.L.B. #13	1081 GL	1982 ft
130		Union Oil Co. C.D.L.B. #14	1090 GL	3176 ft
131		Union Oil Co. C.D.L.B. #15	973 RT	5336 ft
132		Union Oil Co. C.D.L.B. #16	991 RT	2095 ft
133		Union Oil Co. C.D.L.B. #17	1007 KB	3800 ft
134		Getty Oil Co. Tapo fee #43	1150 GL	2593 ft

Well Number	Location	Well Name	Elevation	Measured TD
135	Sec. 32 R.3N. R.18W.	Getty Oil Co. Tapo-Scarab #60	1126 KB	3164 ft
136		Getty Oil Co. Tapo #103	1170 GL	3214 ft
137		Getty Oil Co. Tapo #104	1232 DF	----
138		Getty Oil Co. Tapo #44	2386 GL	2302 ft
139		Getty Oil Co. Tapo #45	1225 DF	2215 ft
140		Getty Oil Co. Tapo #46	1214 DF	2032 ft
141		Getty Oil Co. Tapo #47	1171 DF	2184 ft
142		Getty Oil Co. Tapo #49	1193 GL	1785 ft
143	Sec. 35 T.3N. R.18W.	Getty Oil Co. Tapo #4	1193 GL	1785 ft
144		Getty Oil Co. Tapo #12	1267 DF	1432 ft
145		Getty Oil Co. Tapo #15	1300 GL	1360 ft
146		Getty Oil Co. Tapo #16	1248 GL	1000 ft
147		Getty Oil Co. Tapo #17	1188 gL	1425 ft
148		Getty Oil Co. Tapo #18	1198 DF	1670 ft
149		Getty Oil Co. Tapo #19	1195 DF	1280 ft
150		Getty Oil Co. Tapo #20	1195 DF	1562 ft
151		Getty Oil Co. Tapo #21	1176 DF	2018 ft
152		Getty Oil Co. Tapo #22	1286 DF	----
153		Getty Oil Co. Tapo #27	1238 DF	1907 ft
154		Getty Oil Co. Tapo #28	1263 DF	2597 ft
155		Getty Oil Co. Tapo #29	1228 DF	2407 ft
156		Getty Oil Co. Tapo #30	1239 DF	1700 ft
157		Getty Oil Co. Tapo #31	1234 DF	2277 ft
158		Getty Oil Co. Tapo #32	1246 DF	1601 ft
159		Getty Oil Co. Tapo #33	1248 DF	1800 ft
160		Getty Oil Co. Tapo #35	1305 DF	1775 ft
161		Getty Oil Co. Tapo #36	1182 DF	1680 ft
162		Getty Oil Co. Tapo #37	1159 DF	2200 ft
163		Getty Oil Co. Tapo #38	1167 DF	2554 ft
164		Getty Oil Co. Tapo #39	1180 DF	2457 ft
165		Getty Oil Co. Tapo #40	1564 DF	2000 ft
166		Getty Oil Co. Tapo #102	1345 GL	2597 ft
167		R&K Hammerlee Dudley #1	1156 KB	927 ft

Well Number	Location	Well Name	Elevation	Measured TD
168	Sec. 35 T.3N. R.18W.	MacDonald & Norris Water Company #1	1111 KB	3636 ft
169	Sec. 36 T.3N. R.18W.	James B. MacDonald J&H Ranch #1	1105 KB	850 ft
170		James B. MacDonald J&H Ranch #2	1085 KB	297 ft
171		James B. MacDonald J&H Ranch #4	1160 GL	940 ft
172		M. H. Marr Marr Ranch #1	1200 GL	855 ft
174		C&H Anderson Marr #14	1425 GL	1416 ft
175		M. H. Marr Marr Ranch #16	1139 GL	1508 ft
176		M. H. Marr Marr Ranch #23	1162 KB	1200 ft
177		M. H. MaRR Marr Ranch #24	1136 GL	1404 ft
178		M. H. Marr Marr Ranch #25	1192 GL	7644 ft
179		Pacific Western Oil Corp. Marr #1	1168 GL	7644 ft
180		Federal Oil Co. Seargent-Bryce #1	1131 RT	475 ft
181		Federal Oil Co. Water Company #1	1074 KB	442 ft
182		Federal Oil Co. Patterson Ranch #2	1100 KB	652 ft
183		John B. Hetman Schreiber #1	1084 KB	875 ft
184		John B. Hetman Schreiber #2	1081 KB	682 ft
185		Bartlow-Hetman Oil Dev. Co. #3	1038 GL	670 ft
186		Getty Oil Co. Tapo #42		2417 ft
187		Getty Oil Co. Tapo #34	1138 GL	3224 ft
188		Getty Oil Co. Tapo fee #15-A	1340 KB	3221 ft
189		Getty Oil Co. Tapo Fee #250	1190 KB	2678 ft
190		Getty Oil Co. Tapo Fee #260	1240 KB	2850 ft
191	Sec. 26 T.3N. R.19W.	Union Oil Co. Simi #1-26	1002 RT	6500 ft
192	Sec. 34 T.3N. R.19W.	Union Oil Co. Union Moreland Investment #1	742 KB	4862 ft
193		Union Oil Co. O. H.	740 RT	3901 ft
		Moorpark #1 Rd. #2		4438 ft
194	Sec. 35 T.3N. R19W.	Union Oil Co. O.H.	664 RT	8697 ft
		Simi #1-36 Rd. #1		6235 ft
		Rd. #2		7100 ft
195		Central Lease Inc. Simi #30	590 GL	2505 ft
196	Sec. 36 T.3N. R.19W.	Union Oil Co. Oak Park #1	705 KB	4100 ft
197		Union Oil Co. Oak Park #2	937 RT	2694 ft
198		Union Oil Co. Oak Park #3	912 RT	1725 ft
199		Union Oil Co. Oak Park #4	707 RT	1660 ft

Well Number	Location	Well Name	Elevation	Measured TD
200	Sec. 36 T. 3N. R.19W.	Union Oil Co. Oak Park #5	693 RT	1700 ft
201		Union Oil Co. Oak Park #6	935 RT	1337 T
202		Union Oil Co. Oak Park #7	760 RT	1800 ft
203		Union Oil Co. Oak Park #8	676 RT	1690 ft
204		Union Oil Co. Oak Park #9	924 KB	1870 ft
205		Union Oil Co. Oak Park #10	945 RT	1682 ft
206		Union Oil Co. Oak Park #11	958 RT	1530 ft
207		Union Oil Co. Oak Park #12	709 KB	2100 ft
208		Union Oil Co. Oak Park #13	911 KB	1925 ft
209		Union Oil Co. Oak Park #14	889 RT	2700 ft
210		Union Oil Co. Oak Park #16	978 RT	1340 ft
211		Union Oil Co. Oak Park #17	931 RT	900 ft
213		Union Oil Co. Oak Park #19	866 RT	1900 ft
214		Union Oil Co. Oak Park #20	925 RT	900 ft
215		Union Oil Co. Oak Park #21	1004 RT	950 ft
216		Union Oil Co. Oak Park #22	974 RT	1300 ft
217		Union Oil Co. Simi #1-36	915 RT	2710 ft
218		Union Oil Co. Simi #2-36	979 RT	3500 ft
219		Union Oil Co. Simi #3-36	930 RT	6376 ft
220		Union Oil Co. Simi #14	896 DF	5240 ft