AN ABSTRACT OF THE THESIS OF

Matthew E. Richards for the degree of Master of Science in the Department of Geology presented on June 14, 1985.

Title: SUBSURFACE GEOLOGY OF THE SANTA CLARA AVENUE OIL FIELD AND THE LAS POSAS AREA, VENTURA BASIN, CALIFORNIA

Redacted for Privacy

Abstract approved: ______________________

Dr. Robert S. Yeats

In the Santa Clara Avenue oil field, the nonmarine Sespe Formation of Oligocene age has produced 4 million barrels of oil trapped by a Miocene mafic igneous intrusion that cuts across bedding. Throughout most of the oil field, the Miocene and older beds dip about 15° northwest. The intrusion may be related to the outpouring of Conejo Volcanics throughout much of the southern Ventura basin. The Pacific Farms #1 well penetrated 4000 feet of igneous rocks below 5100 feet, whereas wells less than 500 feet to the northwest penetrated Sespe Formation over this interval. The western wall of the intrusion is located by 10 wells which pass repeatedly through the Sespe-intrusive contact. Structure contours on the intrusive contact with the Sespe on the northwest show

that the contact varies from N20°E,80°SE in the southern portion of the field, to N90°E,85°S in the northern end of the field. The southeast wall of the intrusion is not cut by wells, but its location is controlled by a well about 4200 feet southeast of the northwest wall. If the intrusive contact is rotated to its position when it was intruded prior to tilting of the middle and late Miocene Modelo Formation, the Sespe overhangs the igneous body along a contact with a paleo-dip of 80°NW. Lateral closure in the field may be due to early Miocene normal faulting of the Sespe Formation.

In the Las Posas area, two faults are documented. Both faults cut the entire Miocene section but do not cut the Pliocene-Pleistocene Pico Formation. The Miocene Vaqueros is found only on the south side of the Las Posas fault. Intra-Sespe correlations show that the upthrown block of the Las Posas fault lost to erosion 1000 feet of Sespe in addition to the Vaqueros Formation. The Epworth syncline and Berylwood anticline were folded prior to the deposition of the Pico Formation.

SUBSURFACE GEOLOGY OF THE SANTA CLARA AVENUE OIL FIELD AND THE LAS POSAS AREA, VENTURA BASIN, CALIFORNIA

by

Matthew E. Richards

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed June 14, 1985

Commencement June 1986

APPROVED:

Redacted for Privacy

Professor of Geology in Charge of major

Redacted for Privacy

Chairman of department of Geology

Redacted for Privacy

Dean of Graduate School

Date thesis is presented June 14, 1985

Typed by Harvey McCloud for Matthew E. Richards

ACKNOWLEDGEMENTS

The subsurface data were gathered from Conoco, the California Division of Oil and Gas and Petroleum Information. Financial support was provided by MCOR Oil and Gas Co., Texaco Philanthropic Foundation scholarships (awarded by the Dept. of Geology) and Union Oil of California.

I thank Dr. Yeats for his support, advice and patience throughout this project. I also thank Ellen Drake for her helpful comments on this manuscript. I thank Bob Lilly for his helpful and humorous input, particularly in the geophysics portion of this project. I also benefited from discussions with Leonard Stitt of Conoco and Sieg Hamann of Union Oil. Howard Stark provided me with critical well cuttings. I also benefited from numerous discussions with fellow graduate students. I would also like to thank my fiance for her loving support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUBSURFACE GEOLOGY OF THE SANTA CLARA AVENUE OIL FIELD AND THE LAS POSAS AREA, VENTURA BASIN, CALIFORNIA

INTRODUCTION

The Ventura basin is an east-trending trough located within the western Transverse Ranges of southern California (Fig. 1). The present basin came into being at the end of the Miocene, about 5 my ago, and it accumulated up to 7 km of Plio-Pleistocene sediments beneath the Santa Clara Valley (Yeats, 1976). Miocene and older rocks are not geometrically related to the present basin configuration (Barbat, 1958; Yeats, 1976).

The marine Eocene Llajas Formation overlies the Paleocene and Late Cretaceous marine strata in the study area and is itself overlain by the nonmarine Eocene through Miocene Sespe Formation (Seedorf, 1983).

During the middle Miocene, volcanism associated with normal faulting occurred (Yeats, 1968; Campbell and Yerkes, 1976; Yeats, 1983a). The Conejo Volcanics were centered in the Santa Monica Mountains (Williams, 1977). A south-facing subsidence scarp formed as volcanism began (Fig. 2) (Jakes, 1979; Yeats, 1983). Volcanism outlasted subsidence, and the youngest Conejo flows overtopped the

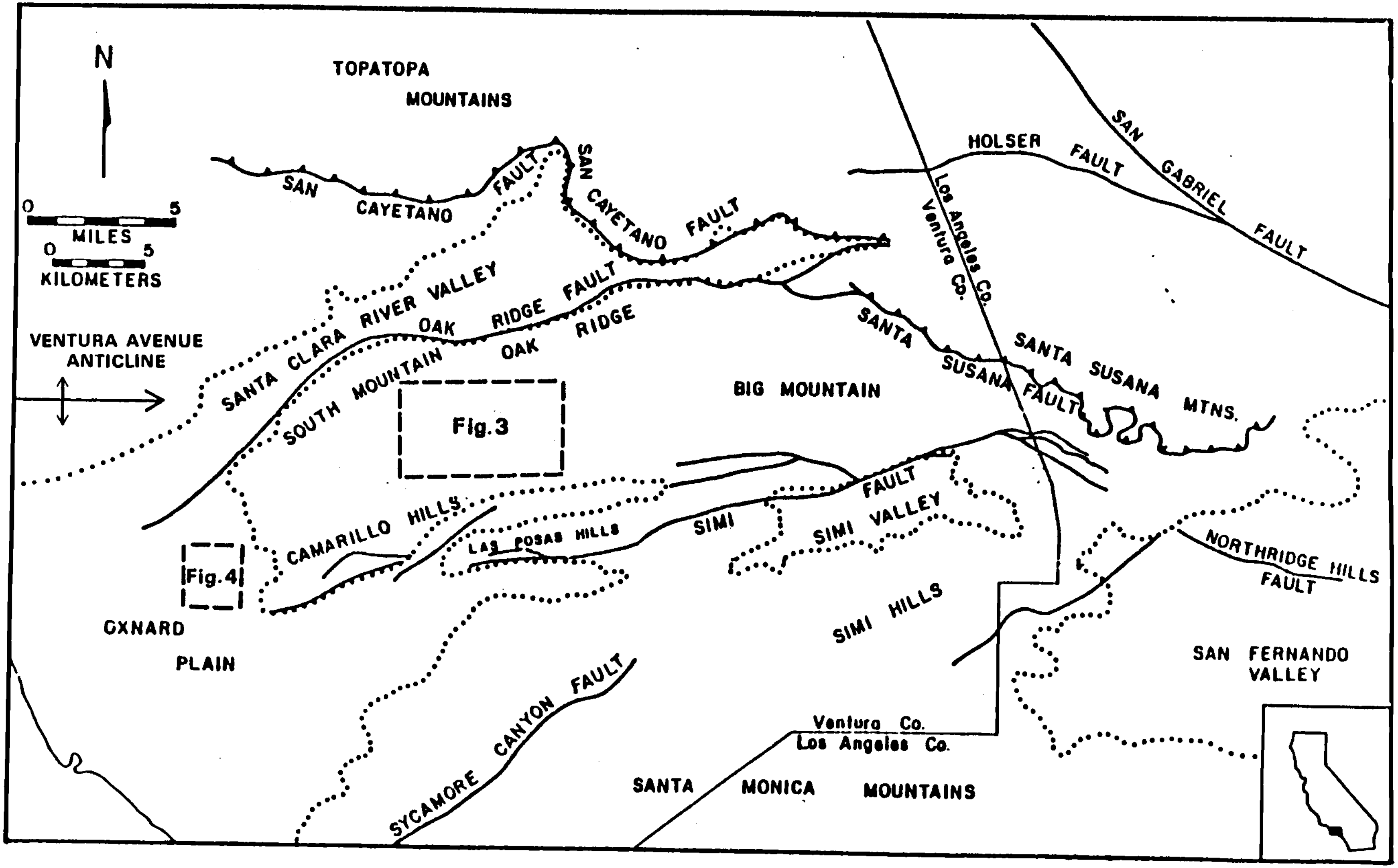

Fig. 1 - Tectonic map of western Transverse Ranges. Study area within dashed boundary (after Jennings and Strand, 1969).

subaerially exposed top of the Sespe north of the Santa Monica Mountains (Yeats, 1983).

The Santa Clara Avenue oil field is located in the south-central Ventura basin, approximately 9 miles east-southeast of Ventura, California, and the Las Posas area is about 9 miles northeast of the Santa Clara Avenue field (Fig. 3). The Santa Clara Avenue field (Fig. 4) was discovered on the broad southeast flank of the Plio-Pleistocene Epworth syncline and has produced 4 million barrels of oil since its discovery in 1972, with a reserve of 2 million barrels of oil (California Division of Oil and Gas, 1983). Flat-lying Pleistocene beds overlie the producing areas such that no evidence of the field is found at the surface, and a two-dimensional gravity-modeling program written by me using the method of Talwani (1959) failed to identify the structure trapping the oil. There may be additional fields similar to Santa Clara Avenue onshore and offshore in the Ventura basin.

This study is intended to work out the time of oil emplacement, the lateral closure, and the configuration of the field at the time of oil accumulation. Then, using Santa Clara Avenue as a model, the same criteria were to be applied to the nearby non-productive Las Posas area to answer the question: is Las Posas a potential oil field?

After work progressed on the project, it became apparent that a comparison of the two areas was not

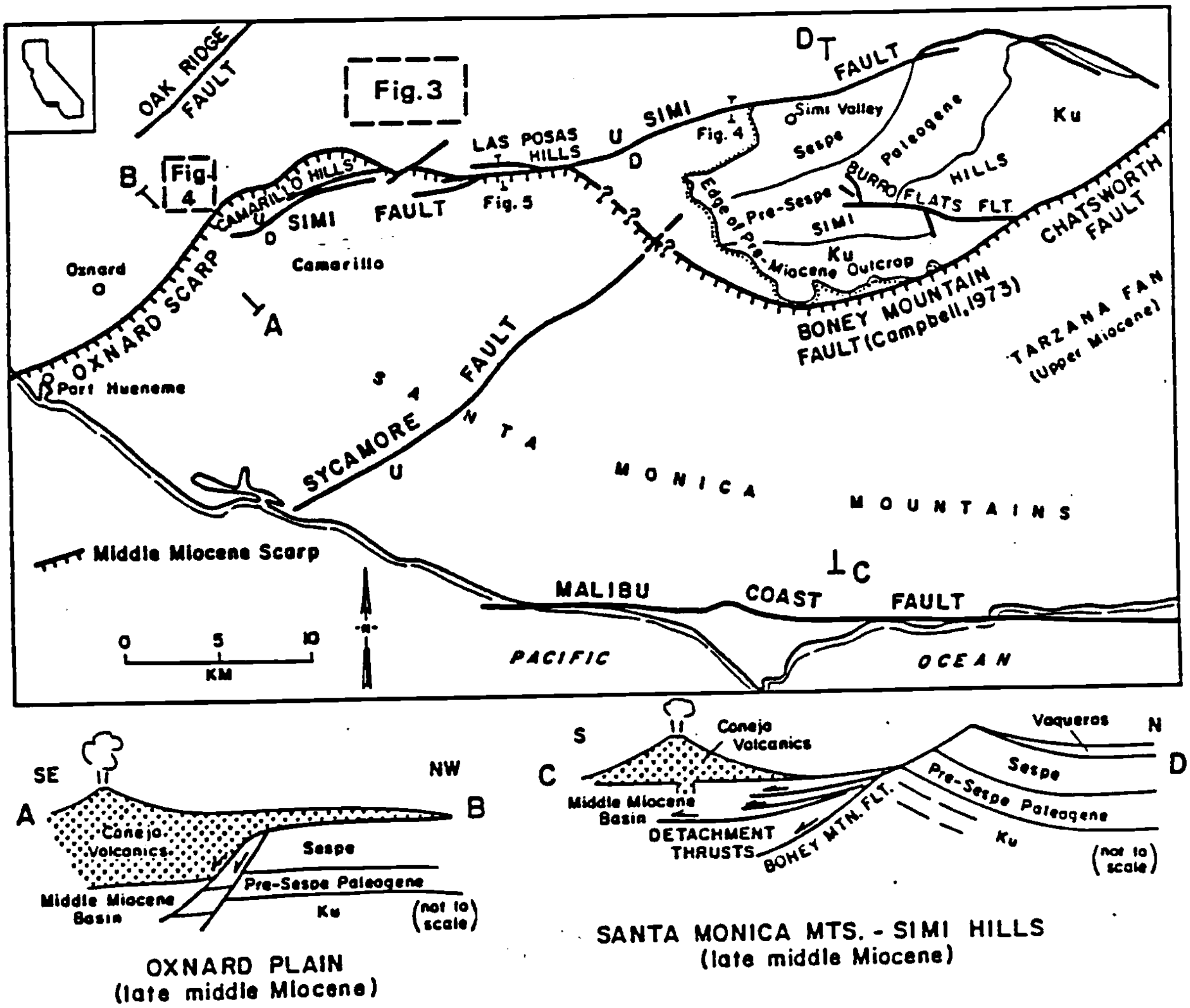

Fig. 2 - Late middle Miocene paleogeographic map (after Yeats, 1983a). Cross sections AB and CD are diagrammatic and not to scale. Study areas within dashed boundaries.

possible. The Las Posas area has no intrusions comparable to the trapping intrusion at Santa Clara Avenue, therefore there is no evidence to suggest where to focus exploration efforts. As a result, this thesis which is being written under the "publication option" will be split into two major discussions: 1) a discussion of the Santa Clara Avenue oil field; 2) a discussion of the Las Posas area. I will then attempt to publish the two studies separately.

Geophysical exploration may define the presence of other intrusions in the Las Posas area such as the one at Santa Clara Avenue. If intrusions are identified, further study of the paleostructure during the time of oil migration may help outline such features.

The structural configuration is documented using data from the Santa Clara Avenue oil field wells and the wells of the Las Posas area. The surface geology at Santa Clara Avenue consists of Quaternary alluvium and terrace deposits, and at Las Posas, the alluvium gives way to exposures of the Pleistocene Saugus Formation. As a result of the limited surface geology, subsurface data were used exclusively.

The cross sections used in this paper are simplified versions of larger-scale cross sections which include electric logs and lithologic descriptions from mudlogs and cores.

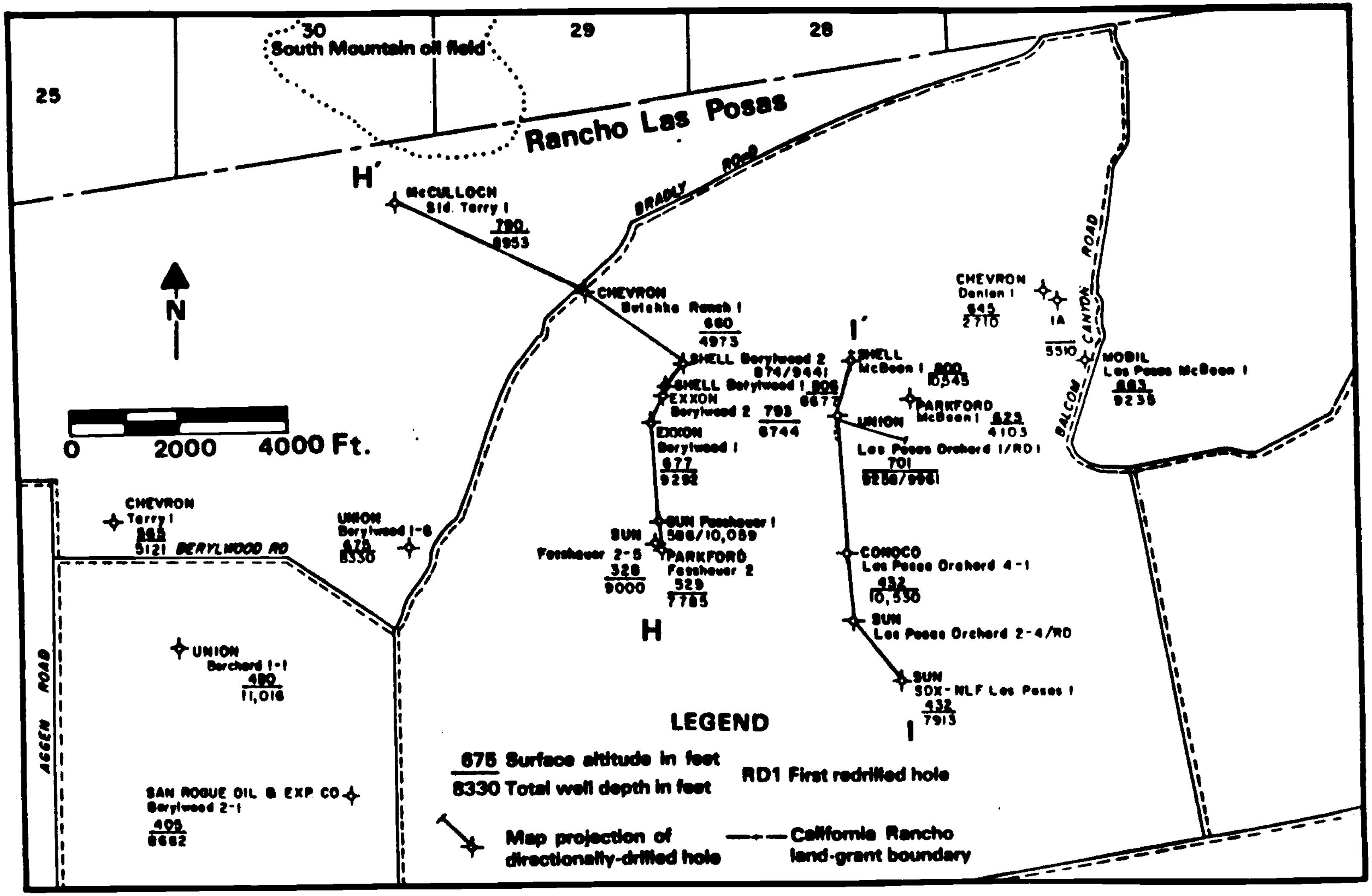

Fig. 3 - Base map of the Las Posas area. H-H' and I-I' are lines of cross section shown in figures 18 and 19.

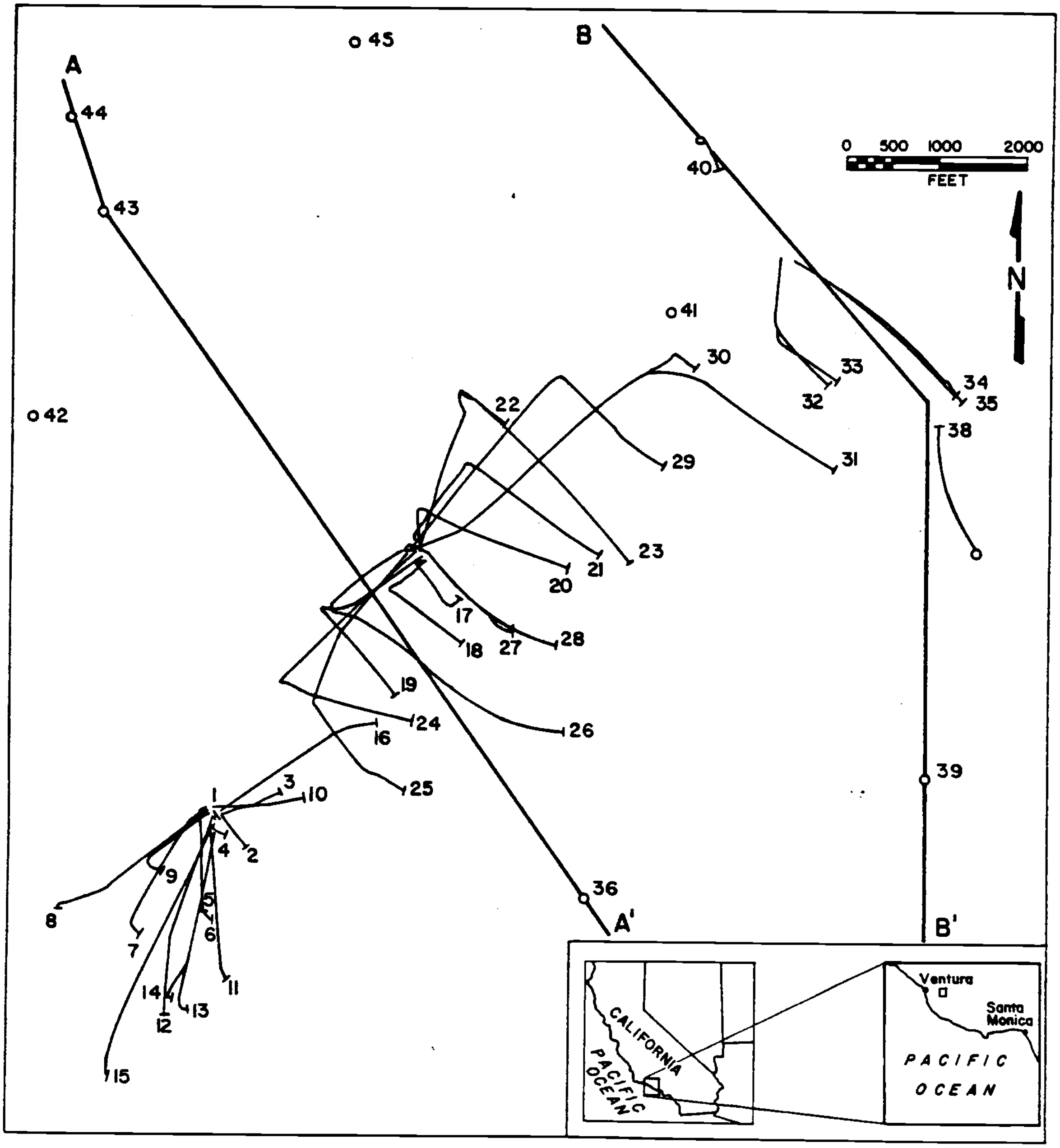

Fig. 4 - Base map of Santa Clara Avenue oil field, California, showing map projection of directionally-drilled wells. Numbered wells identified in table 1. Numbered ticks on well traces are subsea depths in thousands of feet.

Table 1. Key to Well Numbers Used in Text, Maps and Cross Sections

no.	operator	well name	elev	depth
1	Hunnicutt & Camp Drilling Co.	McCulloch-Friedrich #1-25	99	8611
2	"	" #1-25 RD-1	99	8050
3	"	" #1-25 RD-2	99	7700
4	"	" #1-25 RD-3	99	7802
5	"	Friedrich Unit 1#2	100	9516
6	"	Friedrich Unit 1#2A	100	9400
7	"	Friedrich Unit 1#3	100	9036
8	"	Friedrich Unit 1#4	100	9500
9	"	Friedrich Unit 1#4A	100	8862
10	"	Friedrich Unit 1#5	100	8539
11	"	Friedrich Unit 2#1	103	9447
12	"	Friedrich Unit 2#2	104	10165
13	"	Friedrich Unit 2#3	104	10275
14	"	Friedrich Unit 2#3A	104	10695
15	"	Friedrich Unit 2#4	99	11065
16	"	Friedrich Unit 2#4B(=3#2)	99	9986
17	"	Friedrich Unit 3#1	105	10026
18	"	Friedrich Unit 3#3	108	10107
19	"	Friedrich Unit 3#3	108	9670
20	"	Friedrich Unit 3#5	108	10291
21	"	Friedrich Unit 3#6	108	10282
22	"	Friedrich Unit 3#7	108	9785
23	"	Friedrich Unit 3#7A	108	11596
24	"	Friedrich Unit 3#8	108	10755
25	"	Friedrich Unit 3#9	108	11687
26	"	Friedrich Unit 3#10	123	13412
27	"	Friedrich Unit 3#11	123	10661
28	"	Friedrich Unit 3#11A	123	12426
29	"	H&C-MCO-Hunter #1	108	10923
30	"	H&C-MCO-Htr U5-1	108	9520
31	"	H&C-MCO-Htr U5-1A	108	11328
32	"	Sakioka 1	112	9461
33	"	Sakioka 1A RD	112	9163
34	"	Sakioka 2A	112	8978
35	"	Sakioka 2B	112	11027

Table 1. Continued

no.	operator	well name	elev	depth
36	Lloyd Corp., LTD	Friedrich 1-1	81	11005
37	Kenneth H. Hunter, Jr.	Pacific Farms #1	110	8196
38	Kenneth H. Hunter, Jr.	Pacific Farms #1 RD	110	9450
39	Rothschild Oil Co.	Demsey #1	75	3553
40	Exxon	Coffman no. 1	117	10080
41	Texaco	Edwards #1	93DF	6111
42	Victory Oil Co.	Donlon #1	108	7212
43	Kenneth H. Hunter, Jr. Exp.	Central Ave-Furrer #1	128	10500
44	Exxon	Hobson Brthrs Packing Co.	125	10979
45	Texaco	Montgomery 1	112	7384

STRATIGRAPHY OF THE SANTA CLARA AVENUE OIL FIELD

Pre-Sespe Strata, undifferentiated

The Sespe Formation is the oldest unit penetrated at the Santa Clara Avenue field. the Sespe is probably underlain by the marine Eocene Llajas Formation, a pre-Llajas Tertiary marine unit, and the marine Late Cretaceous Chatsworth Formation (Seedorf, 1983). the pre-Sespe sequence is at least 2,650 feet thick in the Oxnard Plain region (Seedorf, 1983).

Sespe Formation

The Sespe Formation consists of nonmarine variegated sandstone and mudstone deposited as a braided river deposit at its base grading upward into a meandering river deposit (McCracken, 1971). The Sespe is easily recognized in mudlogs and cores by its distinctive red and green coloration. The self-potential (SP) and resistivity curves tend to be low amplitude and irregular, whereas the overlying Conejo-Topanga sequence tends to be flat where the strata are volcanic or blocky where the strata are the more massive Topanga sandstone (Fig. 7). The Sespe ranges from 4,000 to 5,000 feet in thickness, as based on wells southeast of the area (Jakes, 1979).

The age of the Sespe Formation based upon vertebrate fossils ranges from late Eocene (Uintan) to early Miocene (Arikareean) (Stock, 1932; Wilson, 1949; Savage and others, 1954; Durham and others, 1954). Lander (1983) and Mason (1983) based on further study of the vertebrate fossils, considered the age as late Eocene to late Oligocene.

There is an angular unconformity between the Sespe and the overlying Miocene. The angle of discordance is about 3 degrees at Santa Clara Avenue (Fig. 5).

Conejo Volcanics and Topanga Formation, undifferentiated

The Sespe is truncated in a southeasterly direction from Santa Clara Avenue by either a low-angle normal fault (Jakes, 1979; Figure 2) or an erosional unconformity (Paschall and others, 1956), and it is overlain by Conejo Volcanics and Topanga Formation undifferentiated. Suzuki (1952) recognized a series of intercalated basalts within the Topanga at the type locality in the Santa Monica Mountains. Three members of the Topanga Formation were defined by Durrell (1954); a lower marine sandstone and siltstone member, a middle member composed of basalt, andesite and dacite interbedded with sandstone (Conejo Volcanics), and an upper marine siltstone and sandstone member. Taliaferro (1924) named the Conejo Volcanics for a section of intrusive and volcanic rocks in the Conejo Hills and the Santa Monica Mountains. Yerkes and Campbell (1979) proposed that Topanga Formation should be the group name for middle Miocene marine and nonmarine sedimentary and volcanic rocks of the Santa Monica Mountains.

Williams (1977) divided the Conejo (or middle Topanga of Durrell, 1954) into three members: a lower member of mainly hyaloclastic deposits, a middle member of altered andesite and basalt flows, and an upper member of breccias, hypersthene basalt flows and platy andesites. Williams (1977) also described intrusions which he was able to separate into three stages: 1) dalcite to basaltic dikes and plugs, 2) hornblende dacite plugs, domes and dikes and 3) dike swarms of porphyritic hypersthene basalt. The younger dikes are indistinguishable in hand specimen and in thin section from hypersthene basalt flows of the uppper member (Williams, 1977).

The age of the Conejo Volcanics, as based upon potassium-argon dating, is 15.5 to 13.90 m.y. (Turner and Campbell, in Yerkes and Campbell, 1979). These dates, taken together with fossil assemblages, provide evidence that the Conejo Volcanics were deposited principally during the Relizian benthic foraminiferal stage of Kleinpell (1938) and partly during the Luisian stage of Kleinpell (1938) (Yerkes and Campbell, 1979).

Topanga sandstone is subordinate at Santa Clara Avenue oil field where volcanics predominate. The Conejo Volcanics are generally about 500 feet thick and thicken toward the southwest to 2,000 feet at the Lloyd Friedrich well (Fig. 5). Jakes (1979) showed that the volcanics thicken in a southeasterly direction to at least 9,000 feet within 1 mile of the Lloyd Friedrich well and to more than 12,000 feet in the Western Gulf Laubacher well east of Port Hueneme (Paschall and others, 1956).

Modelo Formation

In well cuttings, the Modelo is light tan, brown, dark-brown, and brownish black in color. The Modelo consists of light tan, brown, dark-brown, and brownish black shale, diatomaceous shale, silty shale, and siltstone with rarer interbeds of sandstone and volcanic ash. The Modelo locally includes chert and carbonate rocks, and pyrite is also common. At Santa Clara Avenue the Modelo contains a basal tar sand. Glauconite sandstone is found at the Modelo-Pico contact in the Texaco Edwards well.

Foraminifers from the Modelo at Santa Clara Avenue are referred to the Mohnian stage of Kleinpell (1938). The Texaco Edwards #1 well is reported to contain Delmontian foraminifers, but this is unconfirmed; another paleontology report states these may be Mohnian in age. Yeats (1983) reported Mohnian as well as Luisian foraminifers at the Oxnard field south of the Santa Clara Avenue field. Jakes (1979) reported Mohnian and Luisian foraminifers from wells approximately 2 miles northeast of the Santa Clara Avenue field. It is certain that at least part of the Modelo at the Santa Clara Avenue field is Mohnian in age and it seems likely that the basal Modelo is Luisian.

The E-log character is spiky relative to the more blocky E-log character of the overlying Pico and the underlying Conejo (Fig. 7). The spikey character of the Modelo is the result of fine laminations.

Pico Formation

Kew (1924) divided the Fernando Formation of Eldridge and Arnold (1907) into the Pico and the Saugus Formations, with the Pico being the lower, entirely marine unit. The Pico is composed of sandy mudstone, siltstone, and claystone, with thin beds of fine-grained silty sandstone. Van Camp (1959) reported that Pico bedding is commonly contorted, folded and locally graded.

At the Oxnard oil field, the Pico is Pleistocene in age (Yeats, 1983b). These strata are buttressed against the Modelo such that older strata, including Pliocene rocks appear conformably below the Pleistocene to the northwest (Yeats, 1983b). At the Santa Clara Avenue field, the electric log horizon correlated to the Bailey ash bed is constrained between markers P9 and P12, as based upon correlation with Jakes (1979). Izett and others (1974) date the Bailey ash bed as 1.2 0.2 m.y., in agreement with magnetic stratigraphy which places the ash bed in the Matsuyama Chron, below the Jaramillo event (Blackie and Yeats, 1976).

Natland and Kuenen (1951) suggested that the Pico basin was initially deep, but subsidence was less than the rate of accumulation of the sediments, allowing the basin to fill. Yeats (1965) noted that the microfaunal assemblages at Balcom Canyon revealed a shallowing up from bathyal to neritic water depths.

Saugus Formation

The term Saugus Formation is used to refer to the shallow-marine and nonmarine coarse clastic Pleistocene rocks in this area (Yeats, 1983b). The basal Saugus is picked at the base of the Fox Canyon member, which consists of massive, coarse-grained, poorly-sorted sand, pebbly sand and gravel overlain by green marly clay (Fig. 7). The Saugus above the Fox Canyon member consists of nonmarine yellow and gray sand and gravel interbedded with yellow, brown and black clay (Yeats, 1983b). The Saugus is virtually flat-lying in the vicinity of the Santa Clara Avenue field, and its contact with overlying Holocene floodplain deposits cannot be distinguished on figures 5 and 6.

At Santa Clara Avenue the Saugus is 1,200 to 1,500 feet thick. Amino acid raceminzation age estimates on shells within the Saugus on the south flank of the Ventura Avenue anticline yielded ages of between 0.4 to 0.2 m.y. (Yeats, 1983c).

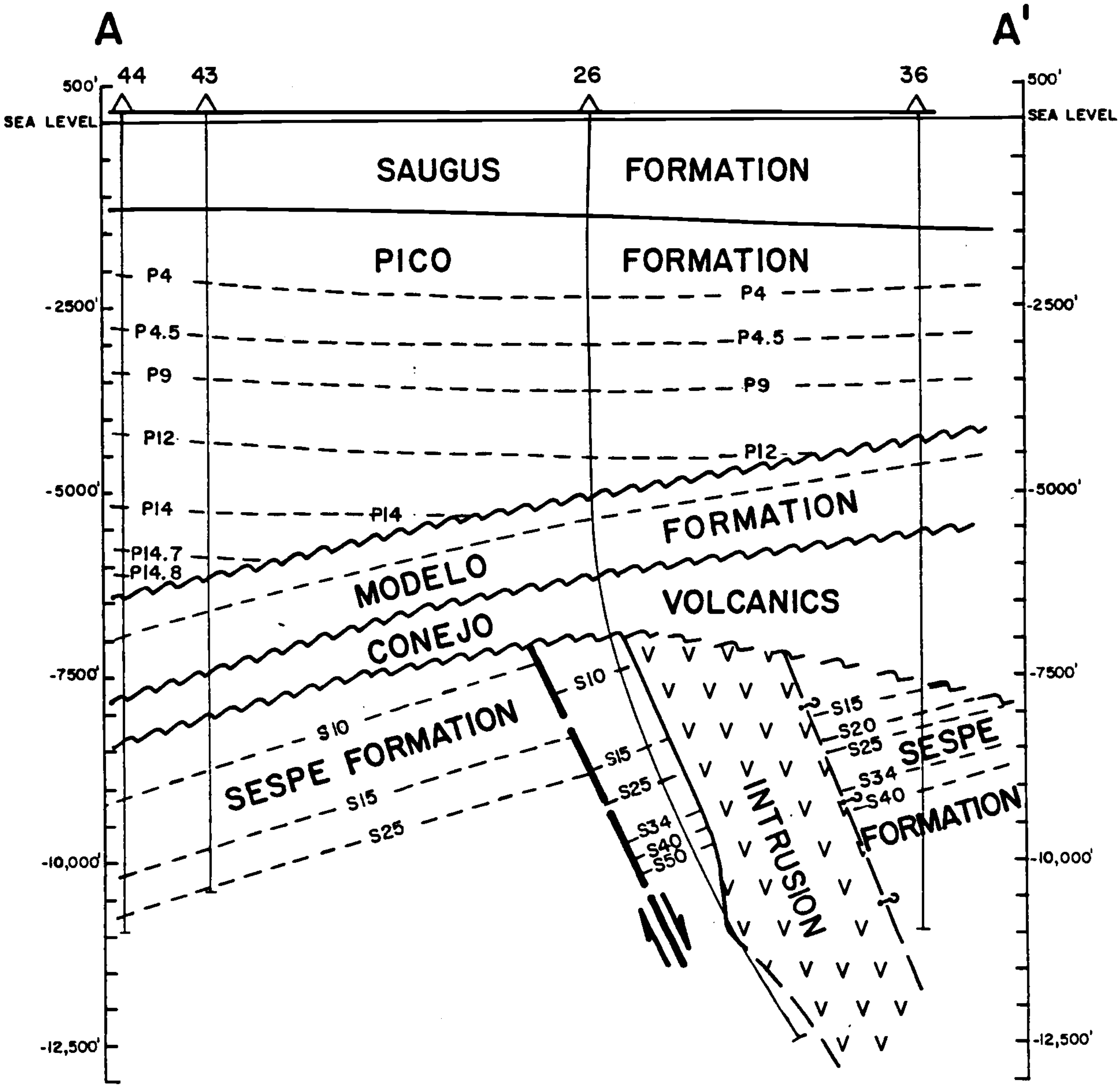

Fig. 5 - Cross section AA'. No vertical exaggeration. Location of cross section lines are shown on base map (Fig. 4). Well numbers identified in table 1. Wavy line indicates unconformity. Dashed lines with letter-number designation are electric log markers.

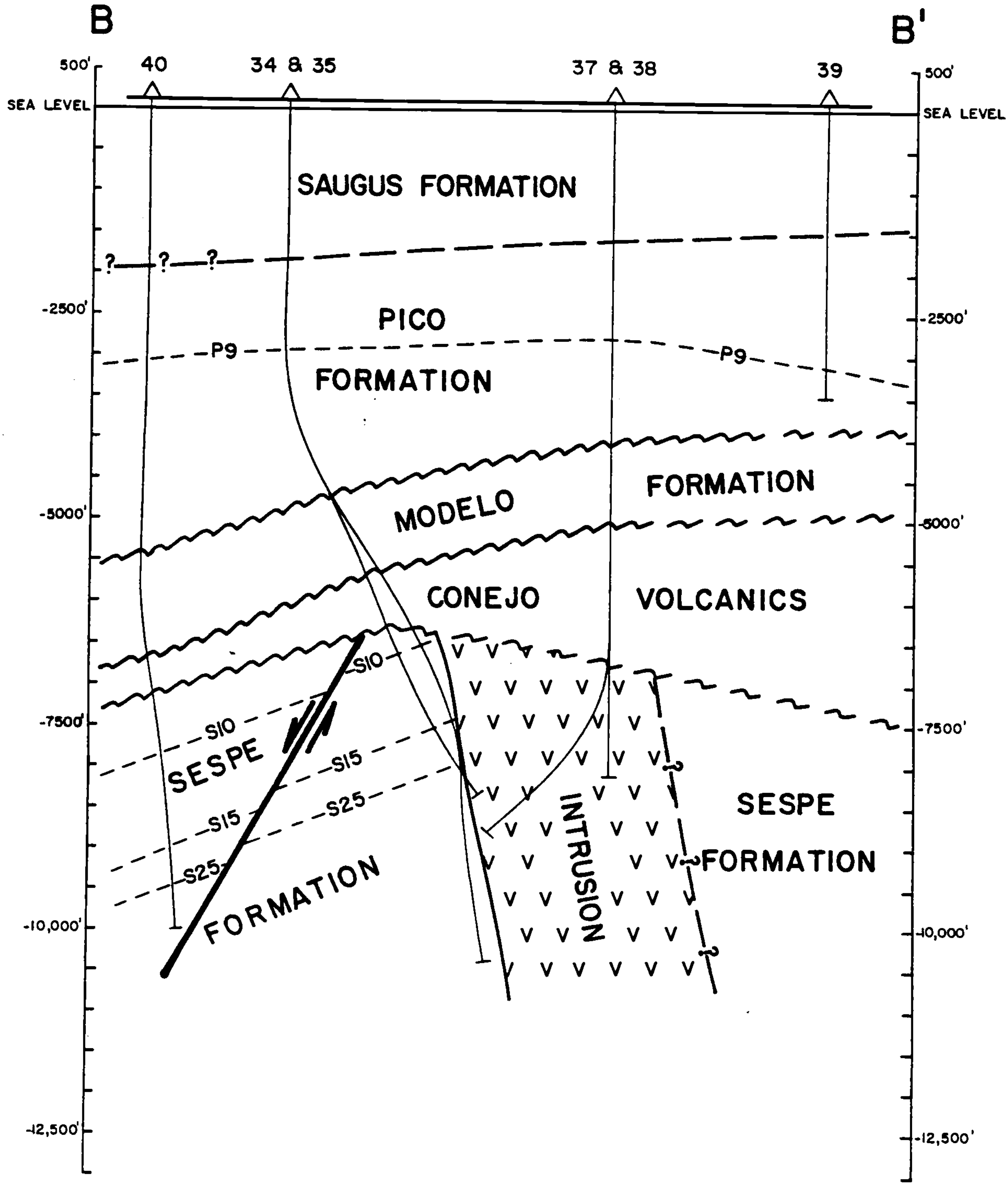

Fig. 6 - Cross section BB'. No vertical exaggeration. Location of cross section lines are shown on base map (Fig. 4).

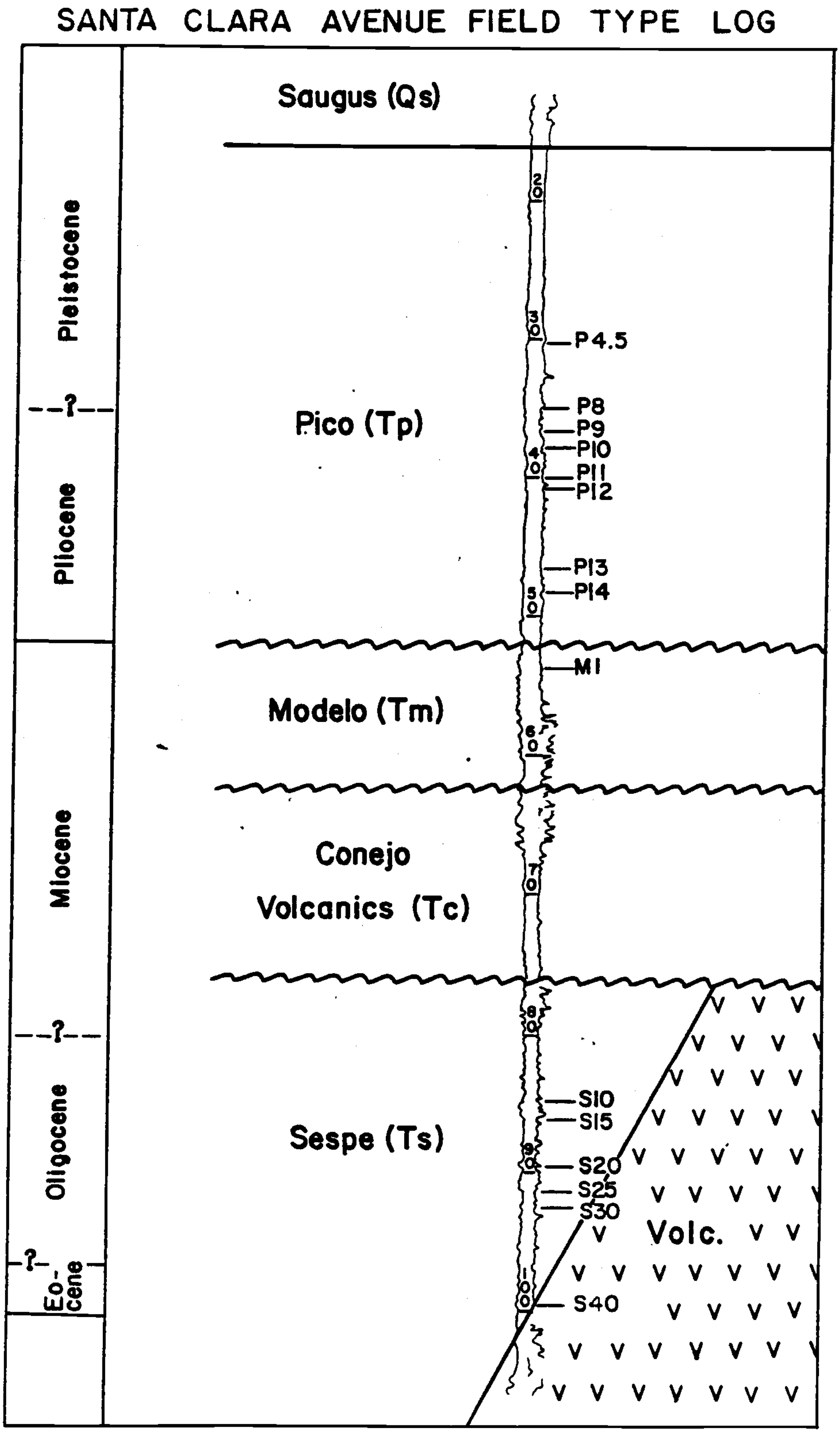

Fig. 7 - Type log, Santa Clara Avenue oil field. Friedrich 3-11 OH.

STRUCTURE OF THE SANTA CLARA AVENUE OIL FIELD

Sespe Faults

The Sespe Formation is cut by normal faults which generally do not penetrate overlying strata (Figs. 5 and 6). Correlation of intra-Sespe markers at the Santa Clara Avenue field (Fig. 8) allows the recognition of several normal faults on the structure contour map (Fig. 9). Similar faults have been documented in nearby areas by Yeats (1965) and Jakes (1979). The stratigraphic separation on these faults at the Santa Clara Avenue field is between 100 and 500 feet. These faults break up the Sespe producing zone into small reservoirs and may provide part of the lateral closure for these reservoirs. The Lloyd Friedrich #1 well (36 on base map) appears down-faulted relative to the field, but this interpretation is dependent on an assumption about the dip of Sespe strata in this well (Fig. 5).

The Simi fault trace, which passes less than one mile south of the Santa Clara Avenue field, was active during the time of deposition of the Conejo Volcanics (Fig. 2) (Jakes, 1979; Yeats, 1983a), such that accumulations of volcanics up to 9,000 feet thick are truncated against

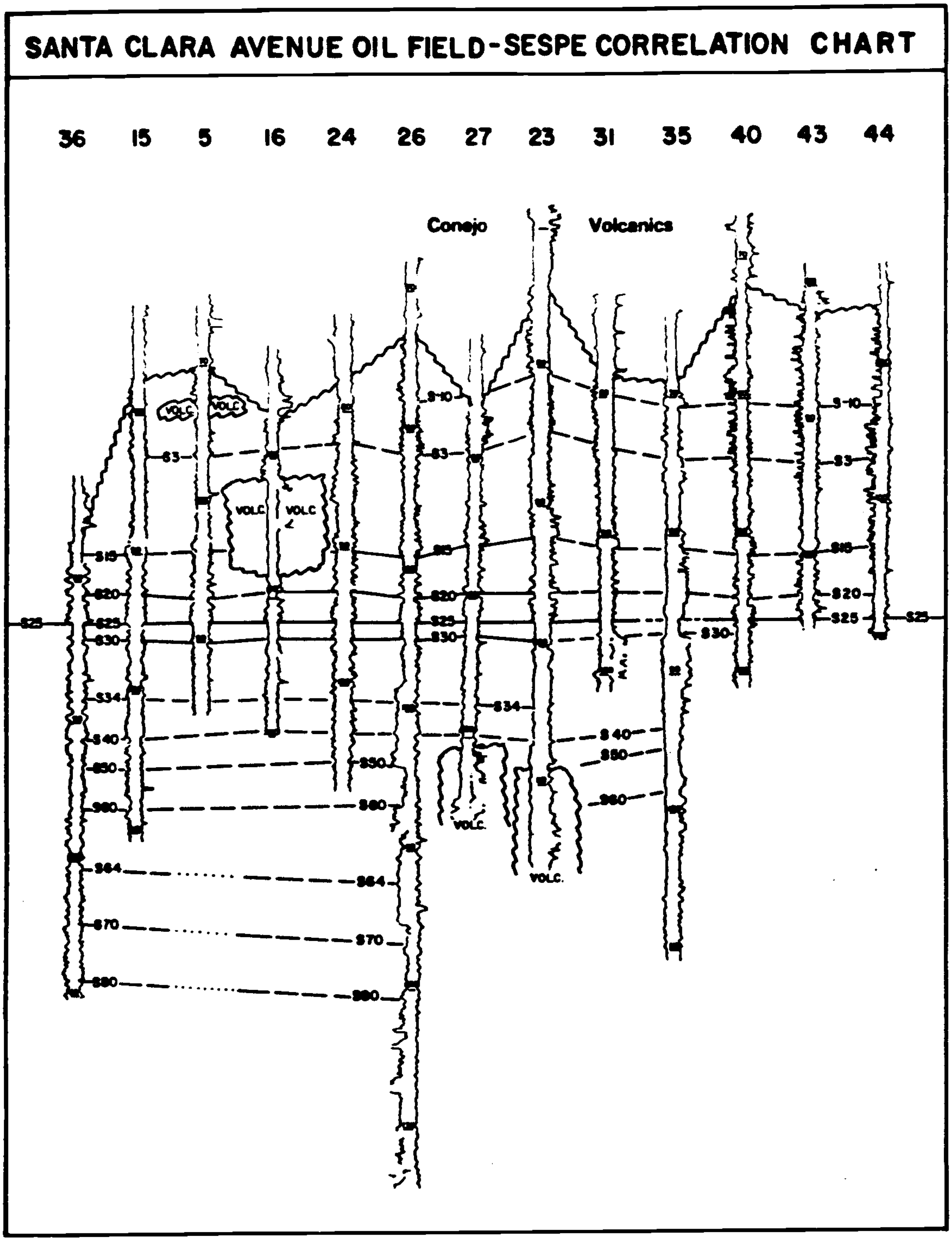

Fig. 8 - Intra-Sespe correlation chart, Santa Clara Avenue oil field. Datum is Sespe electric-log marker 25. No horizontal scale. Upper contact with Conejo Volcanis is an unconformity; other contacts with volcanis are intrusive.

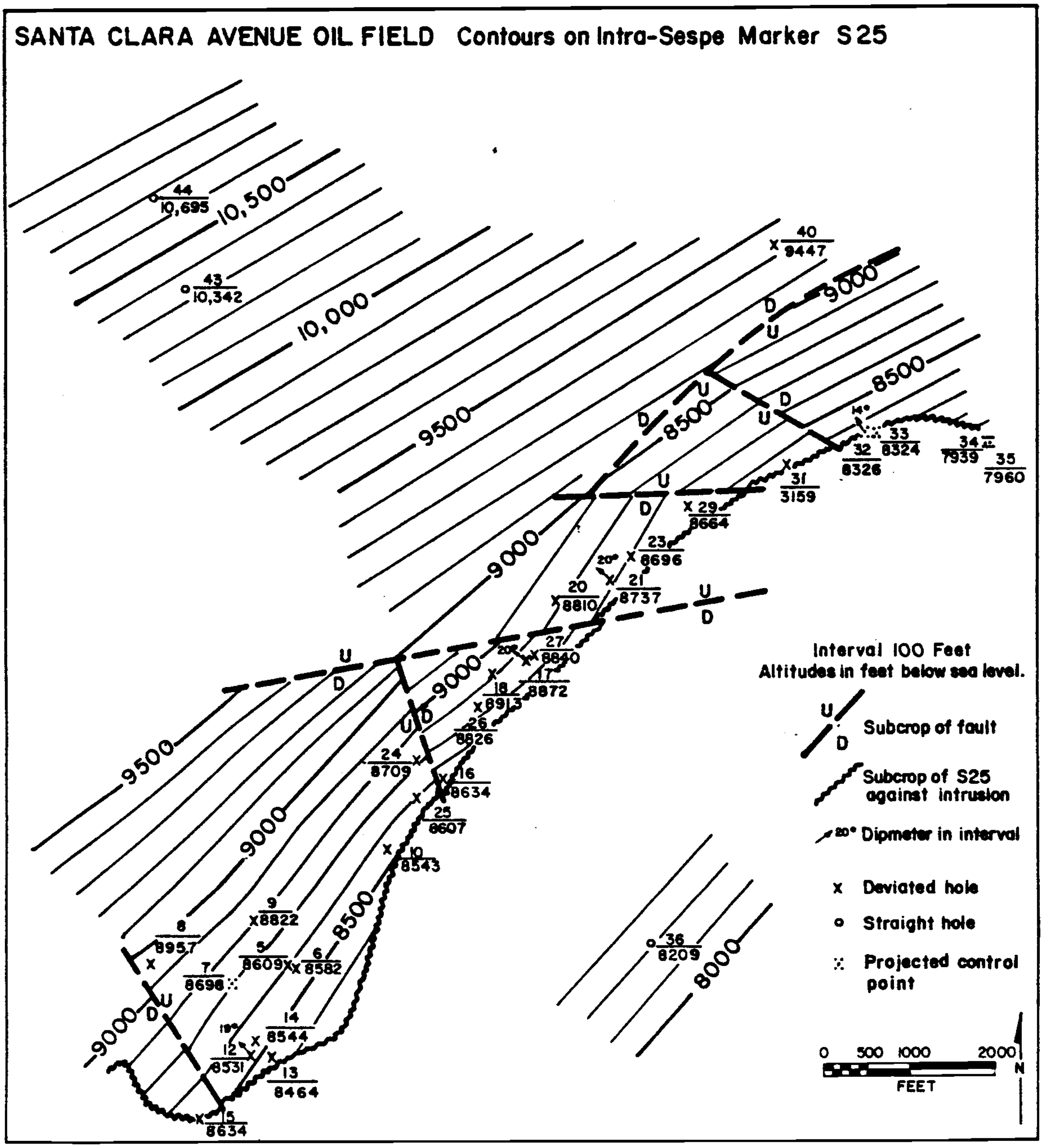

Fig. 9 - Contours on intra-Sespe marker S25.

Sespe Formation at the Simi fault trace. Approximately 500 feet of Conejo overtopped the Simi fault and flowed across an erosion surface of Sespe Formation. If this hypothesis is correct, the Santa Clara Avenue field was on the upthrown side of a major fault which may have removed post-Sespe formations such as the Vaqueros due to erosion prior to deposition of the Conejo Volcanics. The Vaqueros Formation is present northeast of the Santa Clara Avenue field, in the Las Posas area.

Configuration of trap at Santa Clara Avenue oil field

At the Santa Clara Avenue field, the nature of the main trap has been in question since the completion of the discovery well in 1972, McCulloch Friedrich #1-25. The oil is trapped within the Sespe Formation against an up-dip contact with a fine-grained igneous unit. Is this igneous unit a deep canyon fill or is it an intrusion? Because the steep contact with igneous rocks on the south is somewhat similar to the contact between Sespe and Conejo Volcanics at Oxnard field (cf. Fig. 2) it has been generally assumed to be a canyon fill. Sporadic occurrences of volcanic material are logged within the Sespe (Fig. 8), but not in Formations overlying the Conejo Volcanics. Structure contour maps were constructed on the top of the Sespe Formation, where it is overlain unconformably by Conejo Volcanics and at the steep contact with volcanics on the southeast. This map (Fig. 10) shows that the contact between Sespe and overlying Conejo Volcanics dips 22 degrees northwest. But southeast of the Santa Clara Avenue oil field the dip between Sespe and igneous rocks is steep to the southeast. Throughout most of its mapped length, the southeast-dipping surface strikes parallel to the Sespe strike (Fig. 9 and 10) and intersects abruptly the northwest dipping top of the Sespe (Fig. 5 and 6). It is this southeast dipping feature that forms the main trap at Santa Clara Avenue.

The Sespe-igneous contact changes strike in the northern portion of the field to nearly east-west. The southeast-dipping surface is encountered by wells at depths ranging from 7,000 feet to 12,000 feet below sea level. The trap dips at approximately 68 to 88 degrees and may be locally overturned in places. The Lloyd Friedrich #1 well (#30), which is approximately 4,200 feet southeast of the southeast-dipping contact, encounters no volcanics below the top of the Sespe (Fig. 5), evidence that the steeply-dipping igneous body terminates northwest of the well. The Pacific Farms well and its redrill (#37 and 38) did not encounter Sespe and bottomed at 8,887 feet subsea in volcanics (Fig. 6). This gives the minimum width of the feature, because the direction of deviation is approximately at right angles to the strike of the

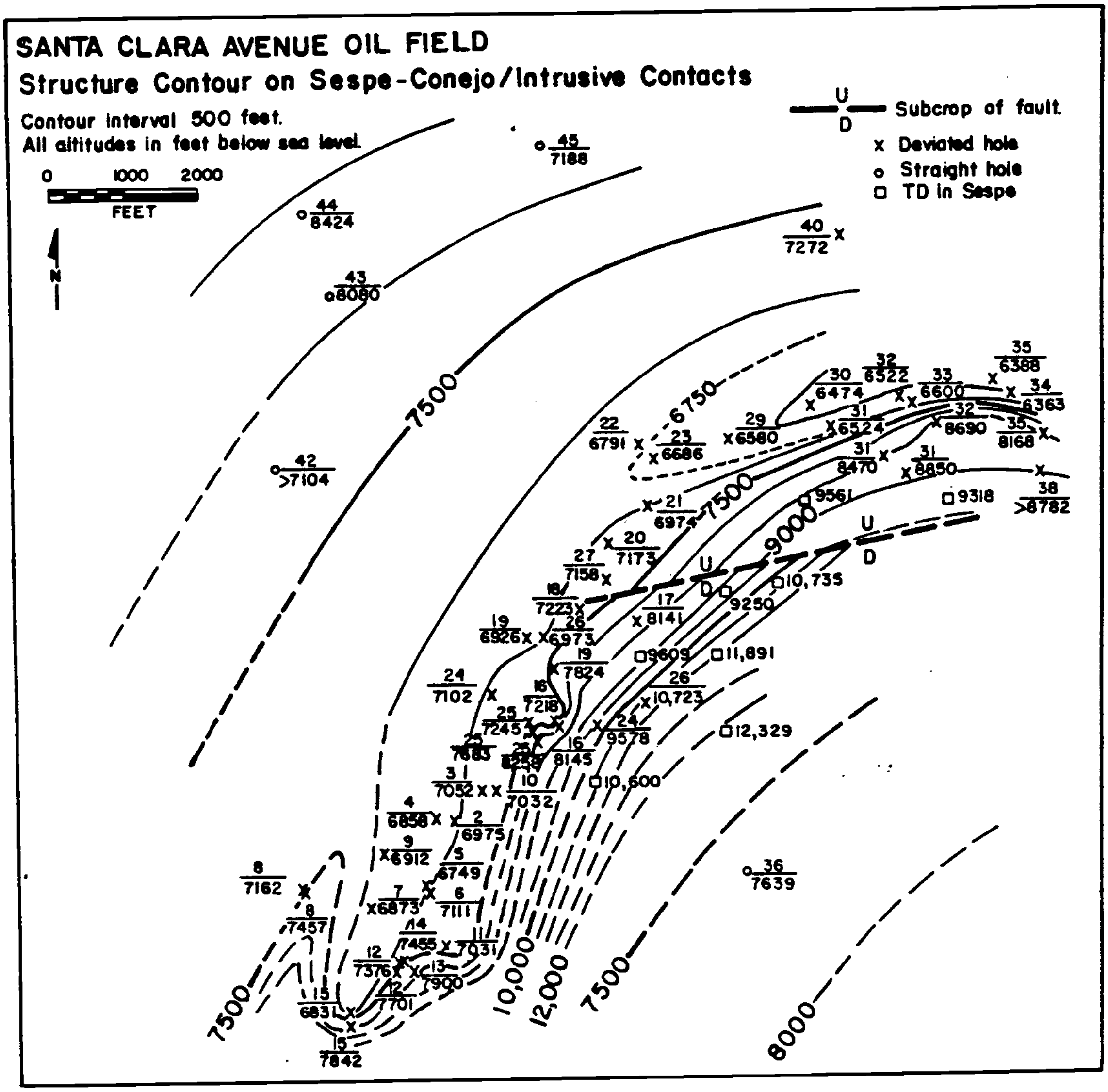

Fig. 10 - Contour map on Sespe-Conejo/intrusion contact.

igneous body in this area. The Conejo above the igneous body and to the northwest is approximately 500 feet thick, and at the Lloyd Friedrich #1 well the Conejo is approximately 2,000 feet thick. This thickening to 2,000 feet of Conejo Volcanics at the Lloyd Friedrich #1 well agrees with the regional increase in thickness of Conejo southeast of Santa Clara Avenue (Paschall and others, 1956; Jakes, 1979; Yeats, 1983b) (shown diagrammatically in Figure 2).

The E-log character of the Conejo Volcanics in the Lloyd Friedrich well appears similar to the Conejo Volcanics in other wells. The Pacific Farms well encounters volcanics which appear to change character with depth. The upper volcanic unit in the Pacific Farms well appears to be similar to that overlying Sespe in the Santa Clara Avenue field and the Lloyd Friedrich well, but at approximately 6,920 feet, a change occurs. Petrographic work done on the ditch samples (no cores were taken) indicate that the upper section contains fine-grained andesite (?), tuff, and volcaniclastic sedimentary rocks; whereas below the 6,920 foot level, fine-grained andesites are found, and no tuff or sedimentary rocks are encountered.

Because the Miocene Modelo marker appears unaffected by the presence of the underlying steeply dipping igneous body, it was probably emplaced prior to deposition of the

Modelo (Fig. 11), either during or prior to emplacement of the Conejo Volcanics. The Modelo marker dips homoclinally to the northwest with one interruption where a small fault cuts it with 200 to 300 feet separation. The Modelo is fine-grained and laminated and was probably deposited in horizontal layers. The high heat flow accompanying volcanism in the southern Ventura basin and Santa Monica Mountains suggests that oil may have been thermally generated at the time of Conejo volcanism, radiometrically dated as 15.5 to 13.9 m.y. (Turner and Campbell, in Yerkes and Campbell, 1979). If so, oil would have accumulated in the structure while the Modelo was still horizontal. By rotating the Modelo back to horizontal, I rotated the Sespe reservoir back to its position at the time oil would have migrated into the structure, based on the estimated time of peak heat flow. In order to reconstruct the pre-Modelo configuration of the field I used an average strike and dip from each Sespe block (Fig. 9) and removed the dip of the Modelo (cf. Fig. 11) directly overlying the block. I did the same for the trapping surface. The rotated trapping surface is overturned in many places and in all other places its dip exceeds 78 degrees (Fig. 12). Dips in the Sespe are rotated so that they dipped southeast when the Modelo was horizontal, with the exception of the three southern blocks (Fig. 12). The presence of rotated Sespe dips to the northwest and

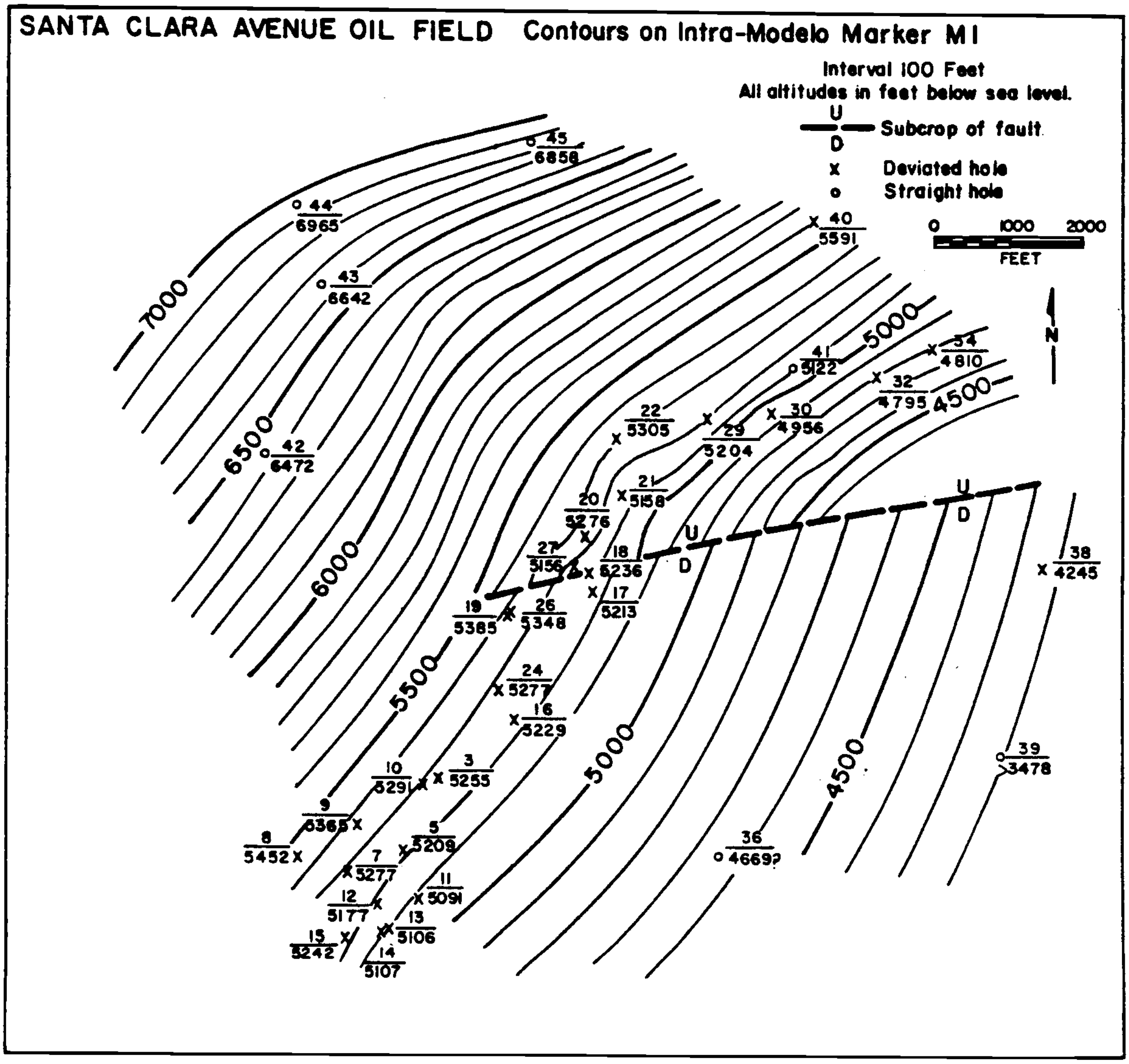

Fig. 11 - Contour map on intra-Modelo marker M1.

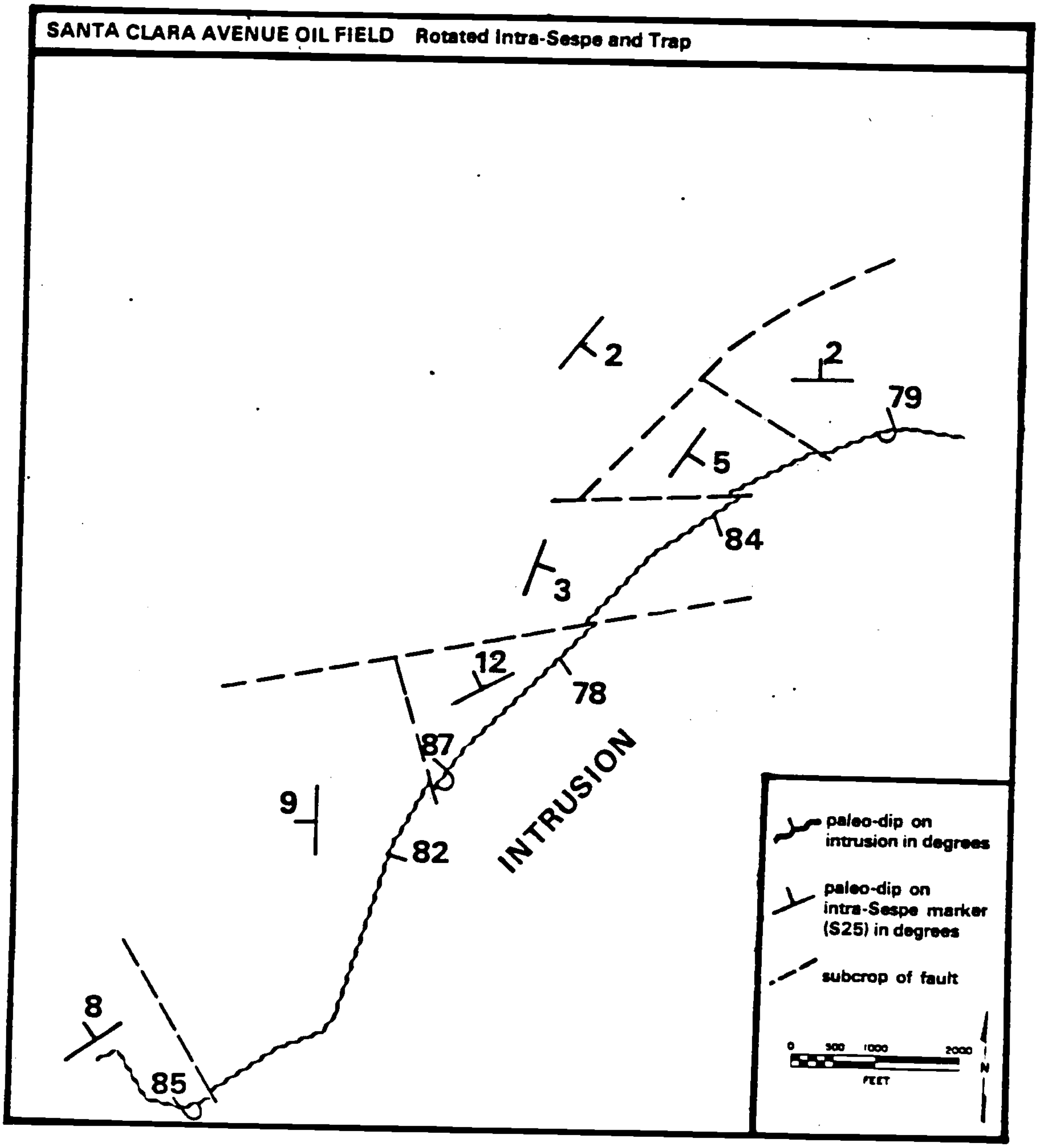

Fig. 12 - Rotated intra-Sespe marker S25 and trap. Attitudes of Sespe bedding and contact with intrusion determined by rotating overlying Modelo Formation to horizontal, its attitude at the time of intrusion and presumably, the time of oil migration into the Sespe reservoir.

southeast at the time of intrusion suggests that the Sespe at Santa Clara Avenue may have been broadly anticlinal at the time, although, data are not sufficient to confirm this. If so, the oil may have moved initially into a trap which was in part anticlinal, and the intrusive contact may have only become significant as a trap after northwest tilting of the Modelo Formation and older rocks.

Interpretation of trap at Santa Clara Avenue oil field

Looking at the data with minimal interpretation gives the following cross section (Fig. 13), which can be interpreted in two ways: a canyon fill or faulted basin model, and an intrusive dike-like model. The canyon model was favored by the original workers at the Santa Clara Avenue field. Initially they had shallower data points on the trapping surface. Because relief on the top Sespe had been documented by other workers in nearby areas (Yeats, 1965), it was assumed that the trap was a paleo-canyon. As control points became deeper with the drilling of successive wells the "canyon" got deeper and steeper

The problems with the canyon hypothesis are seen clearly in an examination of the geometry and composition of the feature. The dips on the northwest wall of the canyon would range from 68-88 degrees and the unseen southeast wall would have to be even steeper. These steep

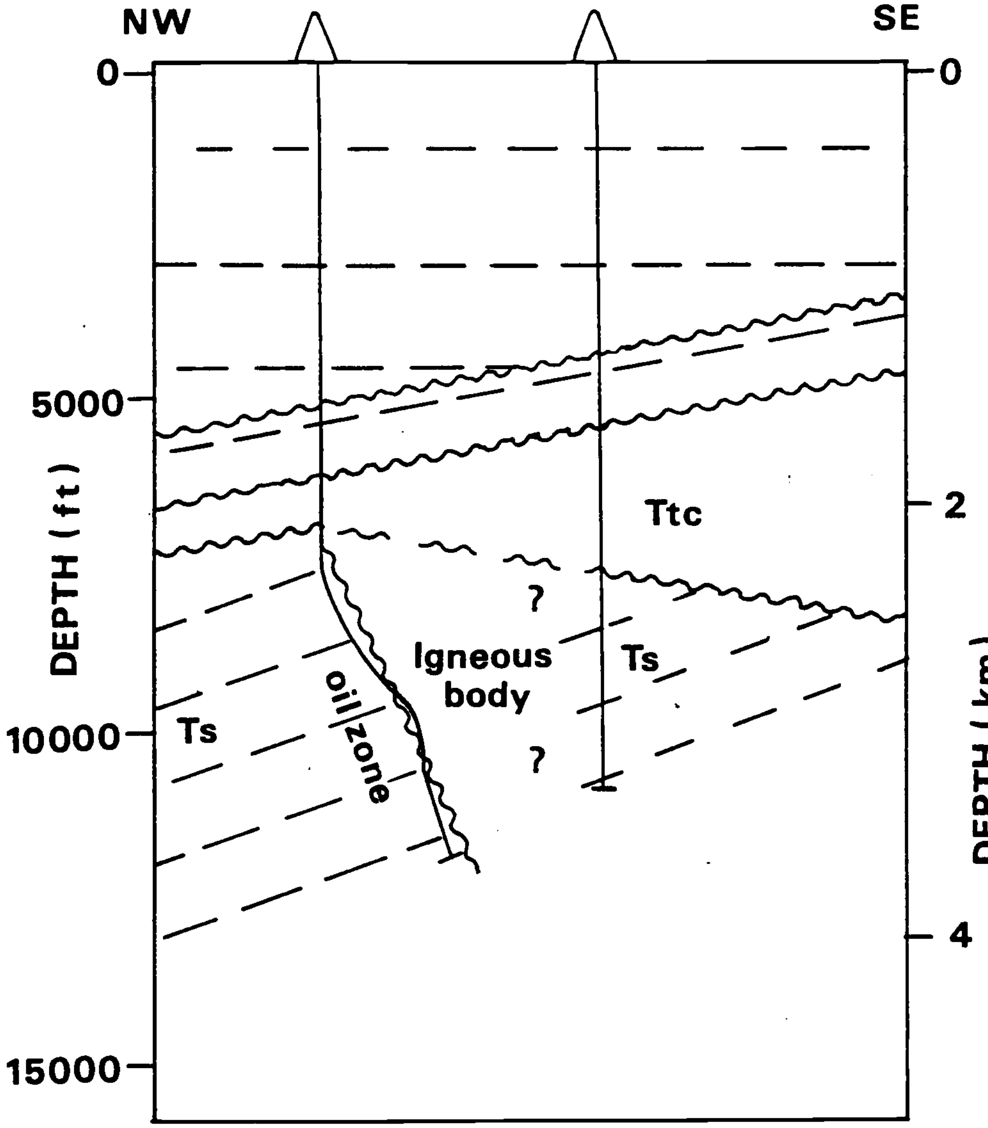

Fig. 13 - Diagrammatic cross section,
Santa Clara Avenue field.
Ts, Sespe Formation; Tm,
Modelo Formation.

canyon walls would then make nearly a right angle turn in less than 2 miles. I know of no modern analog to these extremes. In addition the feature would have to be filled with 5,000 feet of lava flows and nothing else, no sedimentary rocks. Also removal of Modelo dips would cause the feature to have been overturned in many places prior to Modelo tilting. I would also expect the development of dendritic drainage on the rim, but there is no evidence of such drainage, the feature is sharp.

The intrusive model is not affected by the constraints on a canyon. Intrusions can turn and overhang. In addition there are intrusions nearby at South Mountain oil field (Yeats, 1964) and in the Santa Monica Mountains (Durrell, 1954; Williams, 1977). The main problem with this model would seem to be the fine-grained nature of this large intrusion. But the intrusion was emplaced prior to deposition of the Modelo, and thus would have only 1,000 feet of overburden at the time, and ambient formation temperature of the Sespe would have been approximately 117 degrees C. A shallow intrusion would crystallize faster under lower temperatures and pressures forming a fine-grained body.

The Lloyd Friedrich #1 well appears down-faulted relative to the field (Fig. 9). If this fault is real then it could be the conduit along which the intrusion rose. given the abundance of normal faults in the Sespe

Formation, this relationship between intrusion and faulting gives reason to believe that other similar intrusions may exist in other areas, leading to more potential oil traps.

Late Miocene through Pliocene structures

Based upon intra-Modelo correlations and subsequent structure contouring, a late Miocene normal fault was identified at Santa Clara Avenue (Fig. 11). This is the only post Sespe fault found at Santa Clara Avenue. It is likely, but unproven, that it is a reactivated Sespe normal fault (Figs. 9 and 11).

The late Miocene folding resulted in a northwest dip of 14 degrees on the Modelo Formation at Santa Clara Avenue (Fig. 11). If oil migration had occurred prior to Miocene folding then it seems likely that after folding the oil remigrated against the intrusive contact.

After late Miocene folding the Plio-Pleistocene Pico Formation was deposited on the Miocene-Pliocene angular unconformity (Fig. 14). The Pico sands overlapped the unconformity from northwest to southeast. The Pico sands eventually filled the basin and the shallow marine to nonmarine Pleistocene Saugus Formation was deposited conformably over the Pico.

The dip on the Pico sands is approximately 7 degrees southwest (Fig. 15). The deformation may be attributable to Pleistocene reverse movement on the Simi fault to the south (Jakes, 1979; Yeats, 1983a), and the Oak Ridge fault to the north.

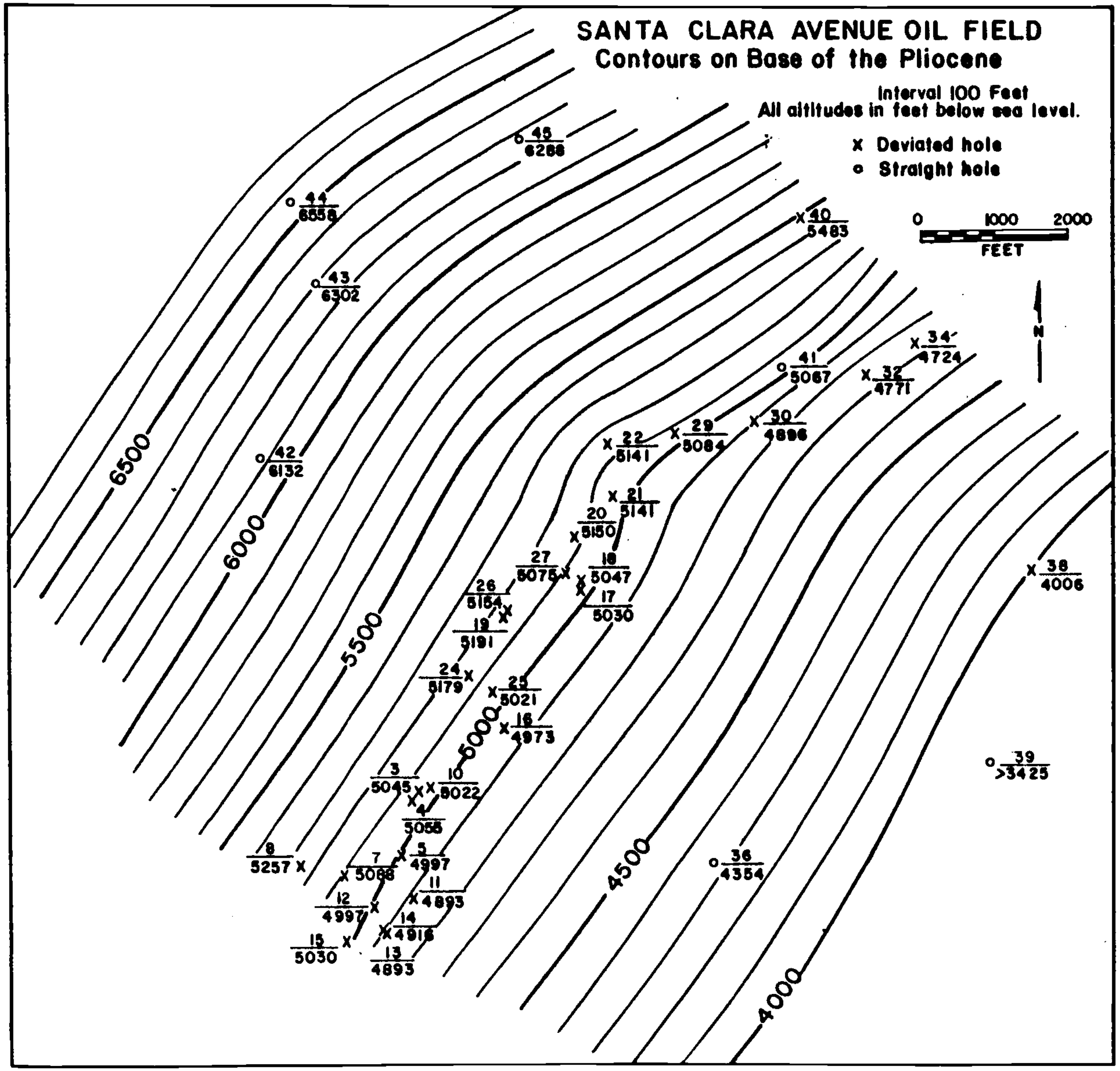

Fig. 14 - Contours on base Pliocene.

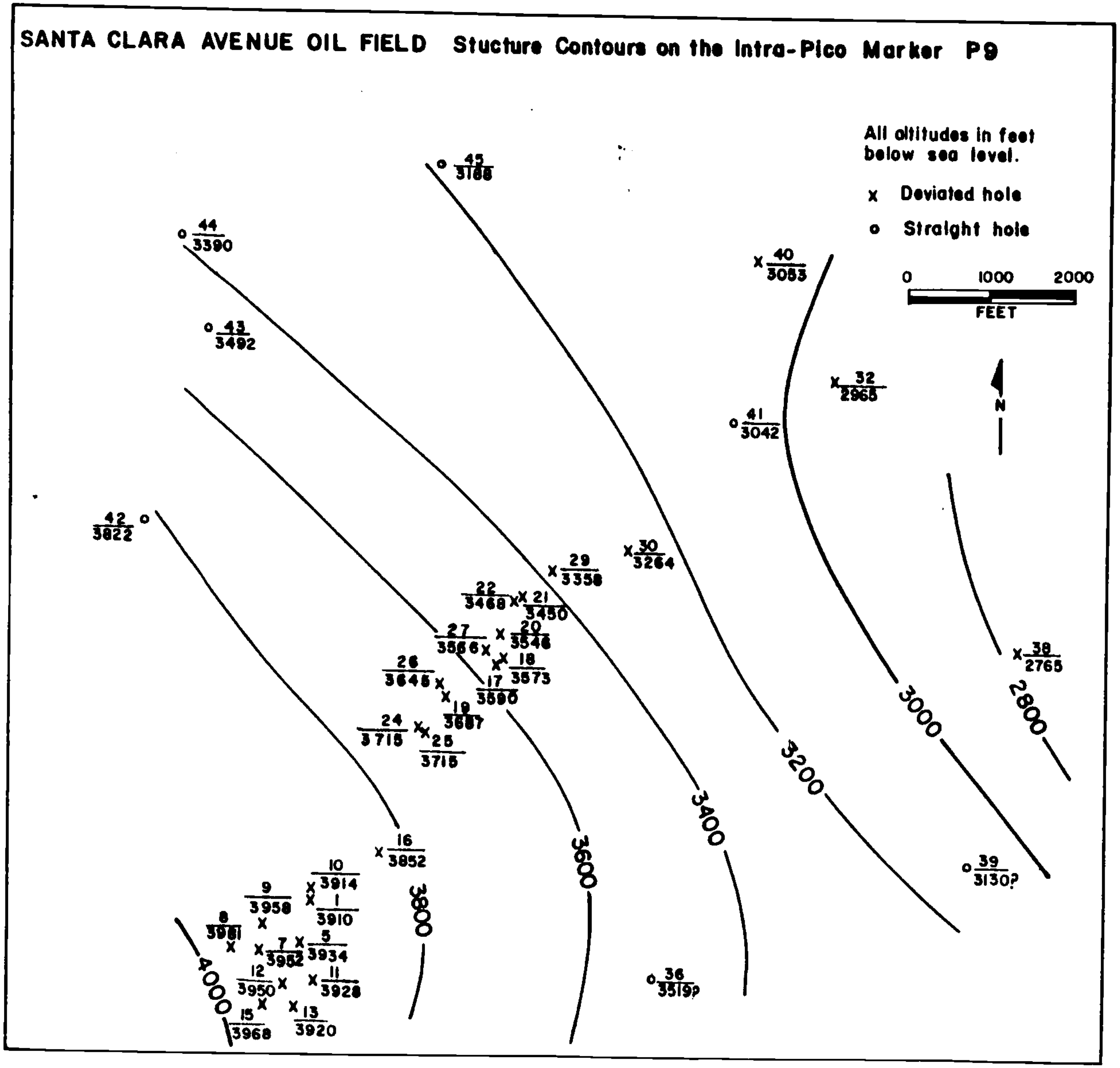

Fig. 15 - Contours on intra-Pico marker P9.

GEOPHYSICS

Introduction

The trapping feature at the Santa Clara Avenue field is invisible at the surface and at horizons above the Sespe due to the unconformities found at the base of the Pico, the Modelo and the Conejo Volcanics. Finding other traps similar to the intrusion at the Santa Clara Avenue field is dependent upon recognizing the trapping feature elsewhere.

Undoubtedly the feature at the Santa Clara Avenue field was a surprise. The trap that was probably being looked for was an updip unconformity occurring as the Sespe-Conejo unconformity changed dip direction from northwest to southeast. Alternatively if my correlation between the Lloyd Friedrich well and the Coffman and other wells -- showing a down to the southeast fault -- is correct then a fault trap may have been the target.

The Santa Clara Avenue field is found within an area affected by Miocene volcanism. North of the Santa Clara Avenue field the Conejo Volcanics are recognized only at the southern margin of the South Mountain oil field, but there is an andesite sill intruding marine Miocene sandstone (Yeats, 1964). The limits of Conejo volcanism will define the areas to target for geophysical exploration in a search for intrusive traps.

Exploring beyond this area for such a trap would be fruitless, unless other volcanic events and their extent are defined. Once the geologic history is known, the geophysical exploration of target areas becomes reasonable.

Gravity

Gravity seemed to be a possible inexpensive method of locating such features. I wrote a gravity modelling program to test the idea that the geometry of the feature at Santa Clara Avenue could be worked out with a simple gravity transect. The program uses the method outlined by Talwani (1959). It was written in BASIC to run on a personal computer.

If the feature were an intrusion, as I believed, then the anomaly would be asymmetrical due to the dip of the feature and the loss of attraction as the feature became deeper (Fig. 17). If the feature were a canyon fill, as had been believed by some of the earlier workers at the Santa Clara Avenue field, then a more symmetrical anomaly would be seen (Fig. 16).

Using density logs, I found that the volcanic material has a density of approximately 2.61 g/cm^3 and the Sespe has a density of approximately 2.31 g/cm^3.

This density contrast of 0.3 g/cm^3, between the Sespe and the volcanic material, results in a total anomaly of just under 4 milligals for the intrusion model (Fig. 17), and just under 2 milligals for the canyon model (Fig. 16). This anomaly would be spread over such a wide area (miles) that it would be unresolvable from the gravitational effects of other structures. The problem is a result of the depth of the feature and its small density contrast with respect to the country rock.

Therefore, gravity appears to offer no help in discerning this particular feature, unless the intrusion is significantly larger and/or closer to the surface.

Magnetics

Magnetic modeling is also possible using a technique which is very similar to the Talwani (1959) method. Given the geometry of the trap -- a 5,000 foot edge -- the feature seems ideal for a strong magnetic anomaly. The composition of the volcanics at the Santa Clara Avenue field is probably andesitic, and this composition may or may not retain a strong magnetic remanence. A detailed magnetic anomaly map of the Ventura basin does not show the feature at Santa Clara Avenue, but it does show the thickening Conejo pile to the southeast (U.S. Geological Survey, 1980). A more mafic intrusion is more likely to be recognized with magnetic techniques.

Seismic reflection

It will be difficult to identify other intrusions such as the one at the Santa Clara Avenue field by seismic reflection techniques. The problem with this technique is the overlying Conejo Volcanics, which causes a density inversion. Most of the seismic energy which encounters the high density Conejo flows will be totally reflected. Because, as mentioned earlier, one would expect the association of intrusions with overlying Conejo flows then it will be a rare circumstance where standard seismic reflection techniques will be able to find these intrusions.

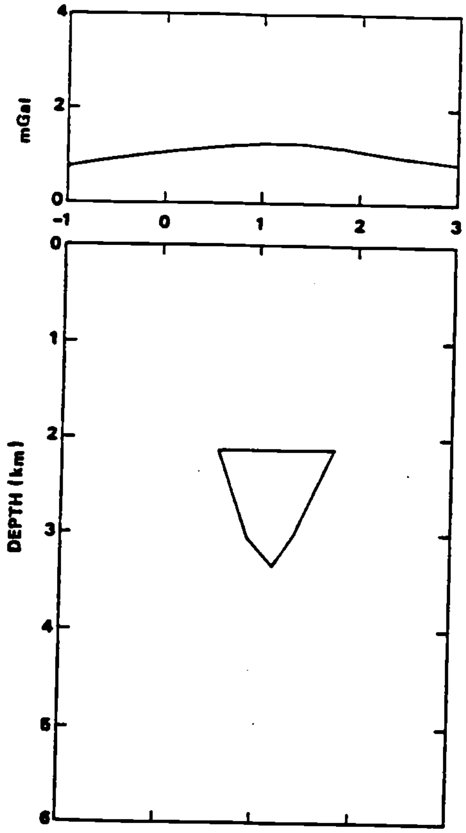

Fig. 16 - Simplified NW-SE model of the Santa Clara Avenue field - canyon model. Density contrast is 0.3 g/cm^3. Note small total anomaly and the long wavelength.

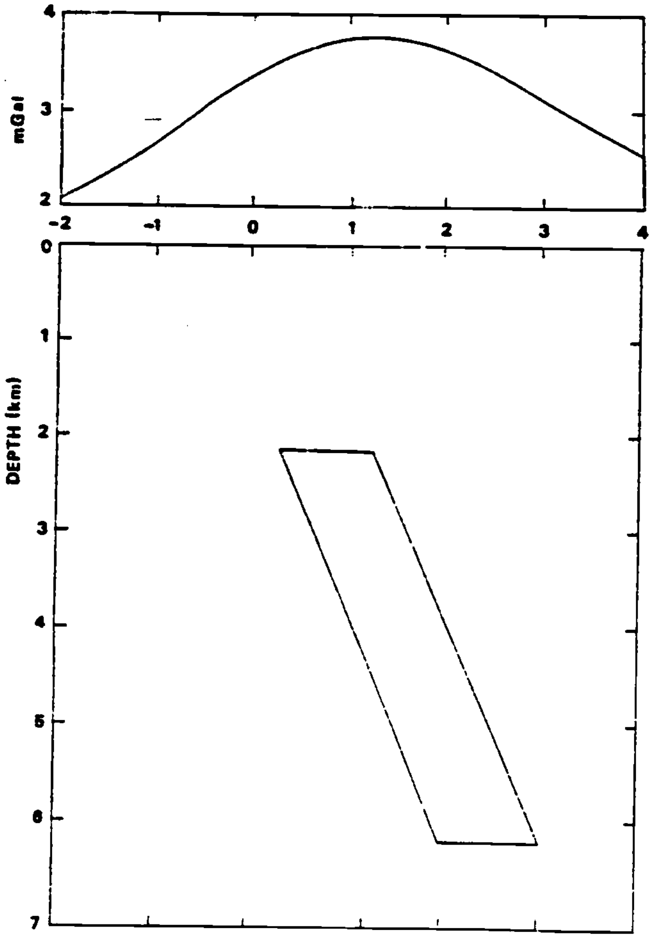

Fig. 17 - Simplified NW-SE model of the Santa Clara Avenue field - dike model. Density contrast is 0.3 g/cm^3. Note small total anomaly and the long wavelength.

STRATIGRAPHY OF THE LAS POSAS AREA

In the Las Posas area 4 wells reach Eocene rocks which are probably part of the Llajas Formation (Figs. 18 and 19). Seedorf (1982) divided the Llajas Formation of the southern Ventura basin into a basal conglomerate and an overlying undifferentiated sequence of light-brown to gray very fine- to fine-grained sandstone. In the Las Posas area the Eocene rocks are seen in the Sun Las Posas Orchard well #2-4 as light gray to dark gray calcareous siltstone and sandstone containing abundant shell fragments.

The late Eocene through early Miocene Sespe Formation in the Las Posas area is approximately 6,500 feet thick north of the Las Posas fault and 7,500 feet thick south of the fault (Fig. 18). This 7,500 foot thick section of Sespe agrees with thickness estimates for the Sespe at South Mountain oil field (R.S. Yeats personal communication, 1985).

East of the Las Posas area, the Vaqueros Formation is broken into three members in the Big Mountain area, a lower transgressive sand, a middle siltstone or mudstone, and an upper regressive sand (Canter, 1974). This section is found in the Las Posas area only south of the Las Posas fault (Fig. 18). The Miocene Conejo Volcanics are approximately 800 to 1,000 feet thick and rest on Miocene marine Vaqueros Formation or on Sespe Formation.

The age of the Vaqueros at Big Mountain is lower to middle Saucesian, with its basal part possibly late Zemorrian (Canter, 1974; Blake, 1983). The Saucesian-Zemorrian foraminiferal stage boundary is believed to be 23.1 m.y.b.p. (Turner, 1970); Obradovich and Naeser, 1981).

The Conejo Volcanics are overlain by the Miocene Modelo Formation. The Modelo is approximately 800 to 1,200 feet thick. In the Sun Fasshauer #1 well Mohnian foraminifers have been collected. The Shell Berylwood #1 well contains Luisian foraminifers, indicating that as in the Santa Clara Avenue area the Modelo is Luisian at its base.

The Modelo is overlain with angular unconformity by the Plio-Pleistocene Pico Formation. The Pico ranges in thickness from 3,800 feet in the Epworth syncline to 900 feet above the Berylwood anticline (Fig. 18). An E-log horizon associated with the Pleistocene Bailey ash bed dated as 1.2 m.y. by Izett and others (1974) is correlated across the Epworth Syncline (Fig. 18). This ash bed can be correlated across the Las Posas fault, where it buttresses against the Miocene Modelo Formation (Fig. 18).

The Pico is overlain conformably by the marine and nonmarine Pleistocene Saugus Formation. In the Las Posas area, the Saugus ranges in thickness from 800 to 1,200 feet (Fig. 18).

Table 2. Key to Well Numbers Used in Text, Maps and Cross Sections - Las Posas Area

no.	operator	well name	elev	depth
46	Chevron	Terry #1	790	5121
47	Union	Borchard 1-1	480	11016
48	San Roque Oil & Exp. Co.	Berylwood 2-1	405	8682
49	Union	Berylwood 1-6	675	8330
50	McCulloch	Std. Terry 1	790	8953
51	Chevron	Butchko Ranch 1	660	4973
52	Shell	Berylwood 2	874	9441
53	Shell	Berylwood 1	806	6677
54	Exxon	Berylwood 2	793	6744
55	Exxon	Berylwood 1	677	9292
56	Sun	Fasshauer 1	586	10059
57	Sun	Fasshauer 2-5	328	9000
58	Parkford	Fasshauer 2	529	7785
59	Shell	McBean 1	800	10545
60	Parkford	McBean 1	625	4103
61	Union	Las Posas Orchard 1	701	9258
62	Union	Las Posas Orchard 1 RD1	701	9961
63	Conoco	Las Posas Orchard 4-1	432	10530
64	Sun	Las Posas Orchard 2-4	448	11866
65	Sun	Las Posas Orchard 2-4 Rd	448	8939
66	Sun-SDX-NLF	Las Posas 1	432	7913
67	Chevron	Donlon 1	645	2710
68	Chevron	Donlon 1A	645	5502
69	Mobil	Las Posas McBean 1	663	9235

STRUCTURE OF THE LAS POSAS AREA

Sespe faults

In the Las Posas area, two normal faults are documented (Figs. 18 and 20). These two faults cut the Miocene section. It is likely, but unproven, that these were reactivated Sespe normal faults. An interesting feature of the Las Posas fault (Fig. 18) is that the Vaqueros Formation is found only on the south side of the fault. Based upon intra-Sespe correlation, there was erosion from the upthrown side of this fault which removed Vaqueros and probably as much as 1,000 feet of Sespe (Fig. 18).

Late Miocene through early Pliocene structures

At Las Posas, the Las Posas and Orchard faults were active after Vaqueros and before Conejo deposition in order to remove Vaqueros. In addition the faults were active during or after Modelo but before Pico deposition (Figs. 18 and 19). Separation of the top Sespe across the Las Posas fault is 1,500 feet wheras separation across the basal Conejo is 150 to 850 feet and separation across the basal Modelo is 200 feet (Fig. 18), indicating faulting of the Sespe prior to Modelo and Conejo deposition. During the Modelo deposition the Las Posas fault allowed for a slightly thicker (100 feet) accumulation of Modelo on the south side of the fault or alternatively the upthrown block underwent submarine erosion (Yeats, 1965) (Fig. 18). Weak intra-Modelo correlations do not indicate a thicker section beneath a marker south of the fault, favoring submarine erosion (Fig. 18).

Evidence that the Berylwood anticline and Epworth syncline were formed prior to the deposition of Pliocene-Pleistocene turbidities is clearly seen in Figure 18. In the cross section, Pliocene markers (drawn on base of sands) onlap the Pliocene-Miocene unconformity within the syncline.

The Las Posas and Orchard faults cut the Miocene Modelo, but do not cut the basal Pliocene Pico sands (Fig. 18). It seems likely that the order of events was as follows: (1) early Miocene faulting after Sespe deposition, but prior to Vaqueros, based on a greater thickness of Sespe above marker -015 on the downthrown side of the Las Posas fault (Fig. 19), (2) continued faulting possibly during but certainly immediately after Vaqueros deposition, removing Vaqueros from the upthrown block of the Las Poras fault, (3) continued faulting during or after Conejo deposition resulting in a thicker section of Conejo on the downthrown side of the Las Posas fault (Fig. 19), (4) faulting after Modelo deposition but prior to Pico deposition, and (5) Pleistocene folding of the area followed Modelo deposition marking a change from extensional to compressional tectonics. There may have been submarine erosion during Pliocene Pico deposition (Yeats, 1965) removing up to 450 feet of Modelo (Fig. 19).

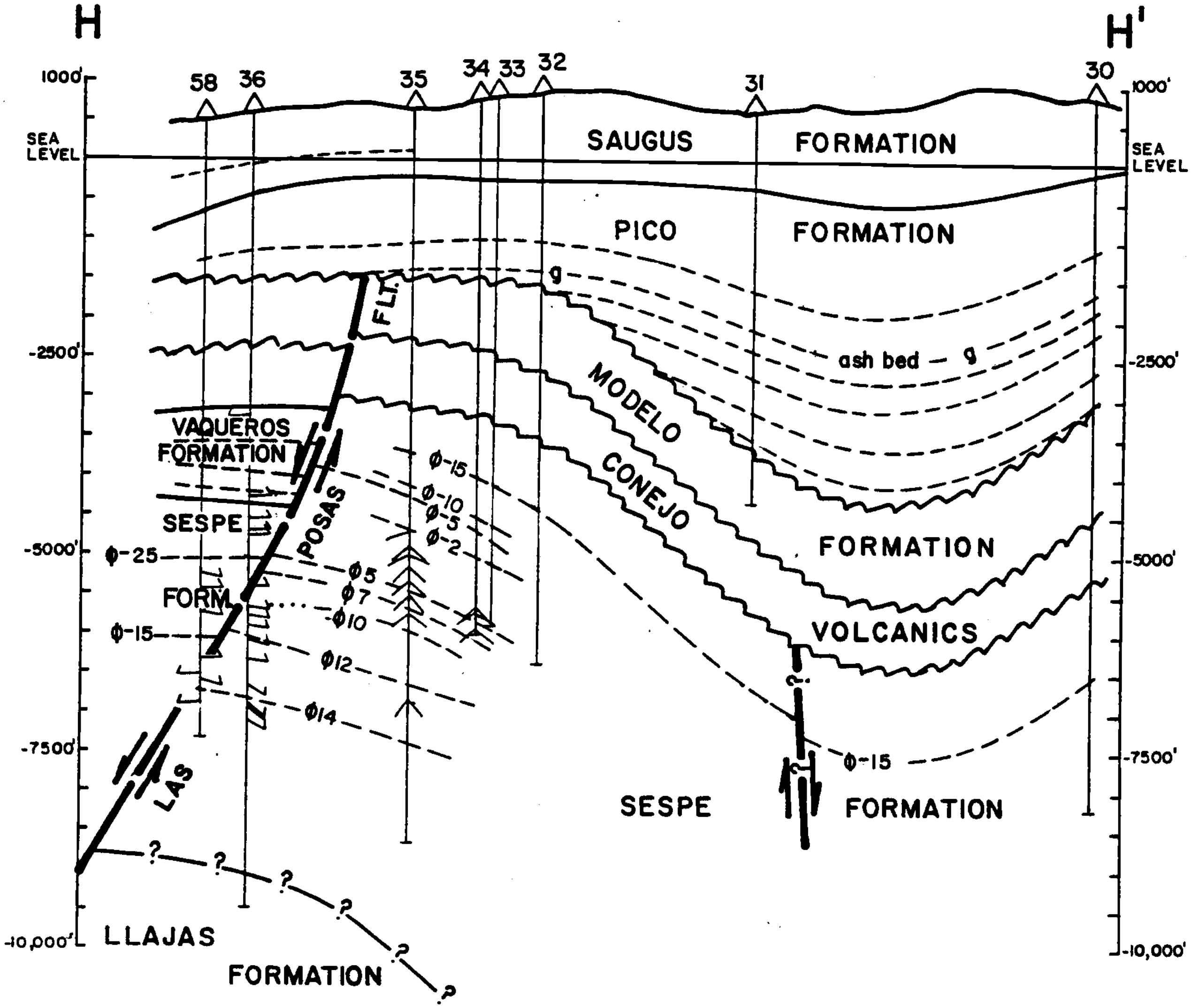

Fig. 18 - Cross section HH'. No vertical exaggeration. Location of cross section lines are shown on base map (Fig. 3). See Fig. 7 for symbols.

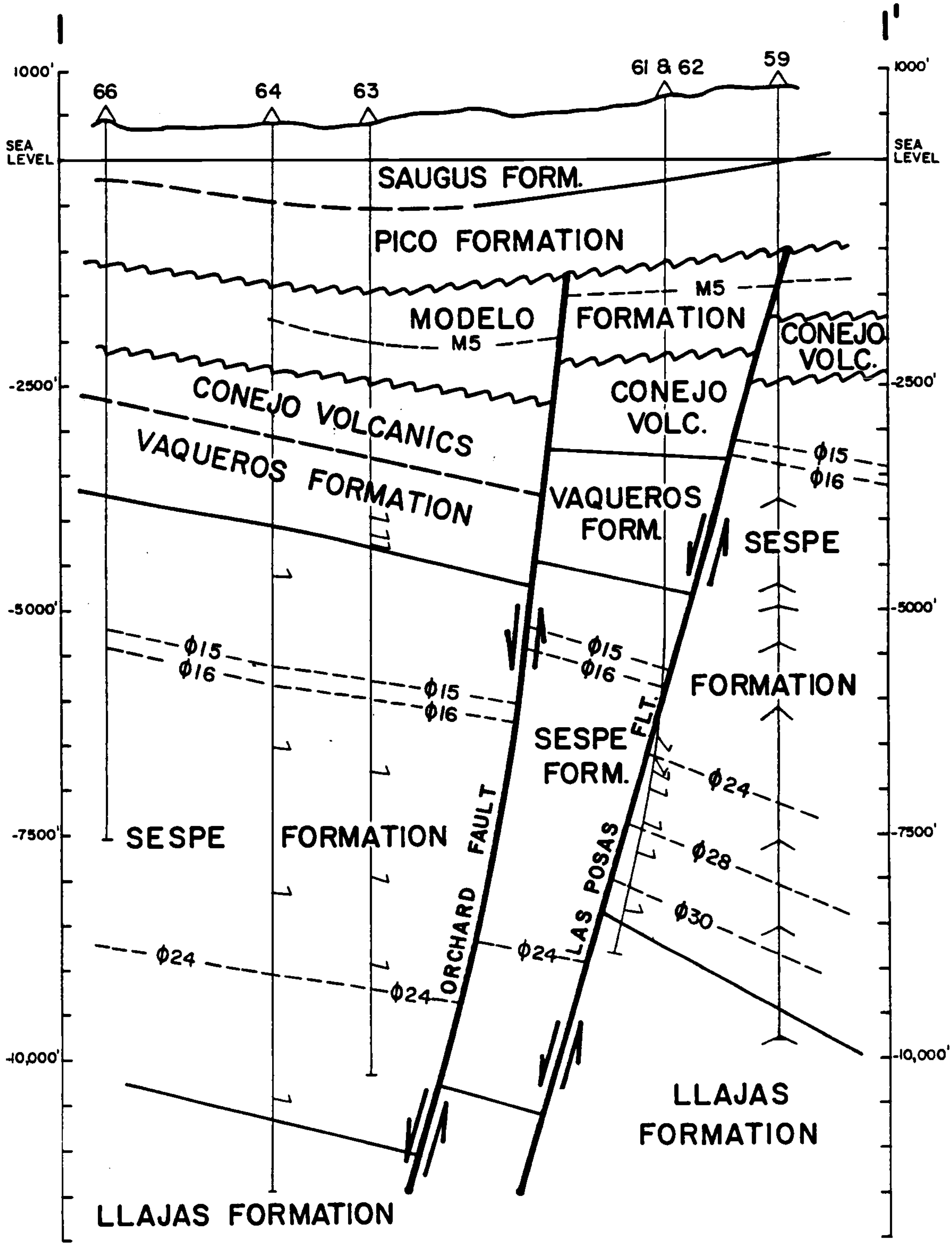

Fig. 19 - Cross section II'. No vertical exaggeration. Location of cross section lines is shown on base map (Fig. 3). See Fig. 7 for symbols.

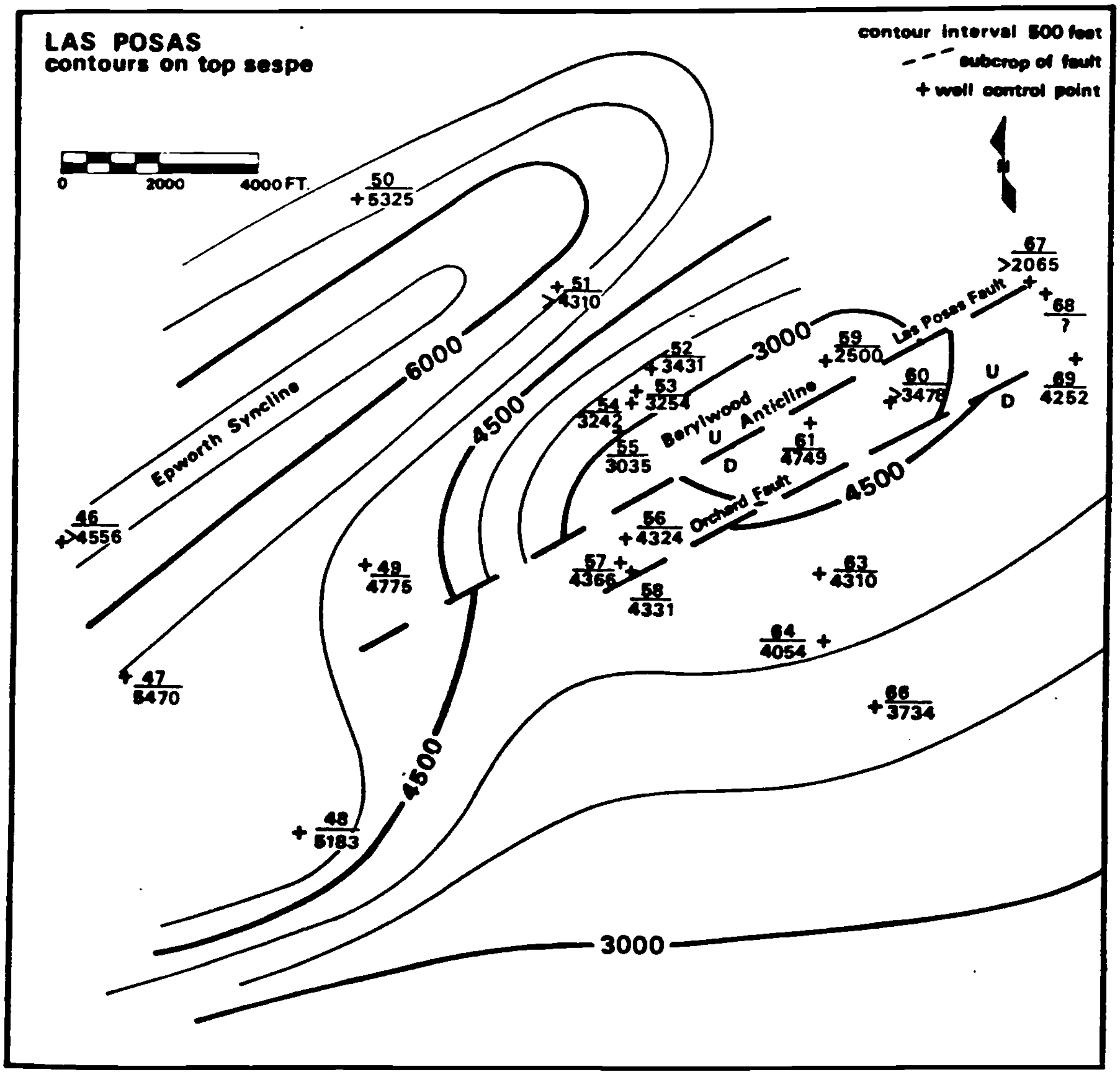

Fig. 20 - Contours on top Sespe.

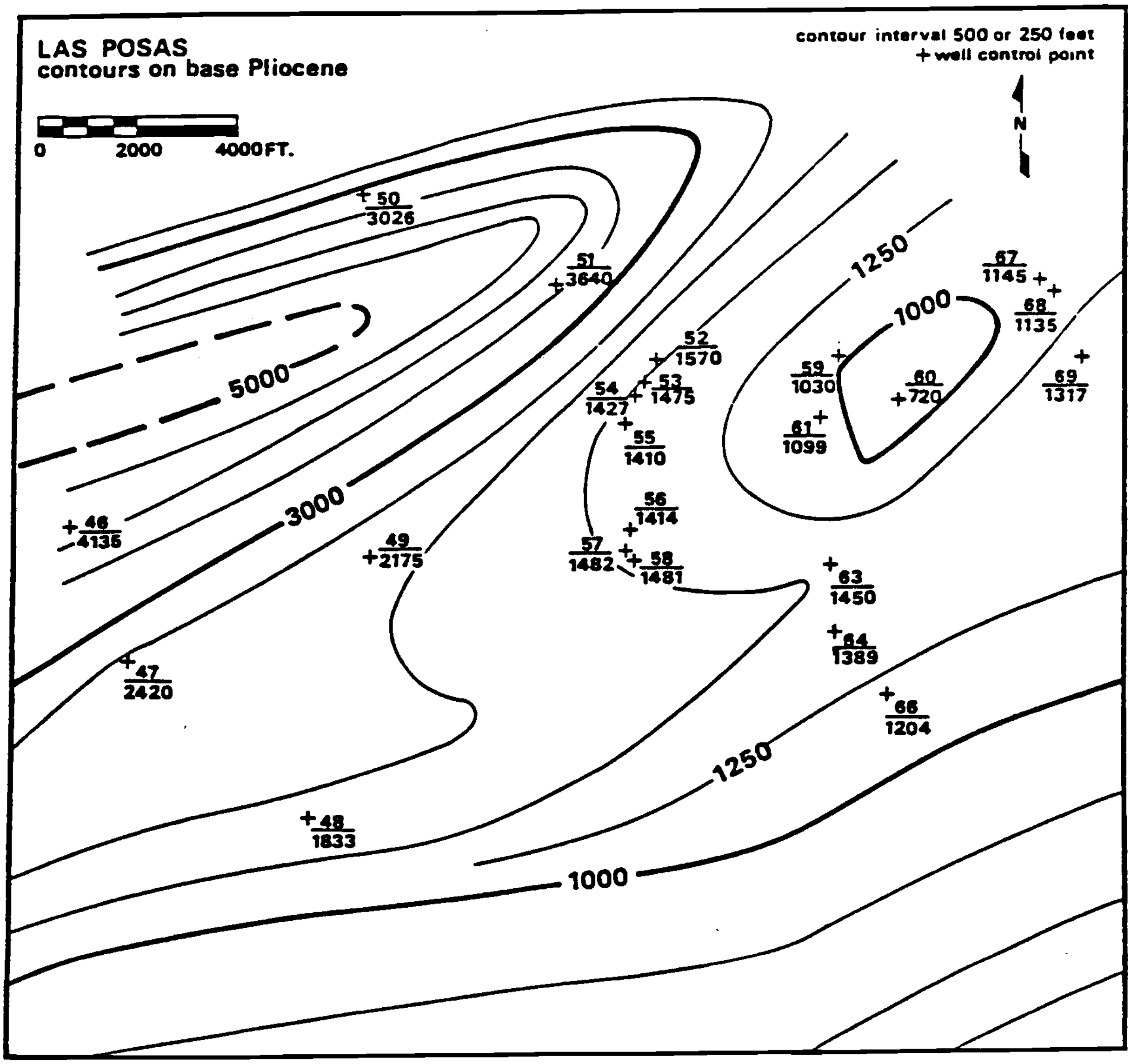

Fig. 21 - Contours on base Pico Formation.

CONCLUSIONS

During early Miocene extension, a south facing subsidence scarp formed as Conejo Volcanism began. This volcanic episode included emplacement of an andesitic dike at the Santa Clara Avenue oil field. It is likely that other intrusions are present in the area. Erosion on the upthrown block, where the Santa Clara Avenue oil field is located, may have removed Vaqueros Formation if it were deposited over this area. Conejo Volcanics overtopped the subaerially exposed subsidence scarp and deposited approximately 500 feet of volcanics over the field.

The Modelo sea transgressed depositing a basal sand and overlying mudstones, carbonates and cherts. Extension was ending as the Miocene ended, and a single normal fault cut the Modelo at Santa Clara Avenue and two faults cut the Miocene at the Las Posas area. Oil migration probably occurred during the Miocene, resulting in accumulations in three of the fault blocks at Santa Clara Avenue. Folding occurred prior to the deposition of the Pico Formation. The Berylwood anticline and Epworth syncline were formed in the Las Posas area. The Santa Clara Avenue oil field is located on the southeast limb of the Epworth Syncline, 9 miles southwest of the Las Posas area. This folding allowed the oil at Santa Clara Avenue to migrate into the remaining fault blocks at the field.

The Plio-Pleistocene Pico turbidities were deposited on this folded surface. The Pico filled the basin as subsidence slowed. The Pleistocene Saugus Formation was deposited in a shallow marine and nonmarine environment. Post Saugus compressive activity on the Simi Fault may have deformed the Pico and the Saugus, resulting in a 7 degree southwest dip at Santa Clara Avenue.

REFERENCES CITED

Arnold, R., 1903, Paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California: California Academy of Science Proceedings, v. 3, p. 1-420.

Bandy, O. L., and Wilcoxon, J. A., 1970, The Pliocene-Pleistocene boundary, Italy and California: Geological Society of America Bulletin, v. 81, p. 2939-2948.

Barbat, W. F., 1958, The Los Angeles basin area, California, in Weeks, L. G., ed., Habitat of oil - A symposium: Tulsa, Oklahoma, American Association of Petroleum Geologists, p. 62-77.

Blackie, G. W., and Yeats, R. S., 1976, Magnetic-reversal stratigraphy of Pliocene-Pleistocene producing section of Saticoy oil field, Ventura basin, California: American Association of Petroleum Geologists Bulletin, v. 60, p. 1985-1992.

Blake, G. H., 1983, Benthic foraminiferal paleoecology and biostratigraphy of the Vaqueros Formation, Big Mountain area, Ventura County, California: in Squires, R. R. and Filewicz, M. V., eds., 1983, Cenozoic geology of the Simi Valley area, Southern California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 173-182.

Brown, R. S., 1959, The geology of the Grimes Canyon area, Ventura County, California: unpublished M.S. thesis, University of California, Los Angeles.

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

Chipping, D. H., 1972, Tertiary paleogeography of central California: American Association of petroleum Geologists Bulletin, v. 56, p. 480-493.

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 Division of Mines, Bulletin 170, Chapter III, no. 7, p. 59-72.

Durrell, C., 1954, Geology of the Santa Monica Mountains, Los Angeles and Ventura Counties, California: California Division of Mines Bulletin 170.

Hanson, D. W., 1981, Surface and Subsurface geology of the Simi Valley area, Ventura County, California: Corvallis, Oregon State University unpublished M.S. thesis, 112 p.

Izett, G. A., Naeser, C. W., and Obradovich, J. D., 1974, Fission track age of zircon from an ash bed in the Pico Formation (Pliocene-Pleistocene) near Ventura, California: Geological Society of America (abstr), Programs, 6, p. 197.

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.

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

Kleinpell, R. M., 1938, Miocene stratigraphy of California: Tulsa, Oklahoma, American Association of Petroleum Geologists, 450 p.

Lander, B. E., 1983, Continental vertebrate faunas from the upper member of the Sespe Formation, Simi Valley, California, and the terminal Eocene event: in Squires, R. R. and Filewicz, M. W., eds., 1983, Cenozoic geology of the Simi Valley area, Southern California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 142-153.

Mason, M., 1983, Fossil land mammals from the Sespe Formation, Simi Valley area, Ventura County, California: in Squires, R. R. and Filewicz, M. V., eds., 1983, Cenozoic geology of the Simi Valley area, Southern California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 141.

McCoy, G., and Sarna-Wojcicki, A. M., 1978, Preliminary map showing surficial materials of the Ventura-Oxnard Plain area, California: U.S. Geological Survey Open File Report OFR 78-1065.

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

Natland, M. L. and Kuenen, P. H., 1951, Sedimentary history of the Ventura basin, California, and the action of turbidity currents: Society of Economic Paleontologists and Minerologists Special Publication 2, p. 76-107.

Natland, M. L., 1952, Pleistocene and Pliocene stratigraphy of southern California: unpublished doctoral dissertation, University of California, Los Angeles.

Nilson, T. H. and Clarke, S. H., 1973, Sedimentation and tectonics in early Tertiary continental borderland of Central California (abstr): American Association of Petroleum Geologists Bulletin, v. 57, no. 4, p. 797.

Obradovich, J. D. and Naeser, C. W., 1981, Geochronology bearing on the age of the Monterey Formation and siliceous rocks in California: in Garrison, R. E. and Douglas, R. G., eds., 1981, The Monterey Formation and related siliceous rocks of California, Pacific Section, S.E.P.M. Special Publication, p. 87-95.

Paschall, R. H., Carson, C. M., Nesbit, R. A., Off, T., and Stark, H. E., 1956, Cenozoic correlation section across central Ventura basin from Santa Ynez Fault north of Ojai to western Santa Monica Mountains, California: Pacific Section, American Association Petroleum Geologists.

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

Seedorf, D. C., 1983, Upper Cretaceous through Eocene Stratigraphy of the Southern Ventura Basin, California: in Squires, R. R. and Filewicz, M. V., eds., 1983, Cenozoic geology of the Simi Valley area, Southern California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 109-128.

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: Proceedings of the National Academy of Science, v. 18, p.

Suzuki, T., 1952, Stratigraphic paleontology of the type section of the Topanga Formation, Santa Monica Mountains, California: Geological Society of America Bulletin, v. 63, pt. 2, p. 1345.

Taliaferro, N., 1924, The oil fields of Ventura County, California: American Association of Petroleum Geologists Bulletin, V. 8, sect. I, p. 789-810.

Talwani, M., Worzel, J. L., and Landisman, M., 1959, Rapid Gravity Computations for Two-Dimensional Bodies with Application to the Mendocino Submarine Fracture Zone: Journal of Geophysical Research, v. 64, no. 1, p. 49-59.

Turner, D. L., 1970, Potassium-argon dating of Pacific Coast Miocene foraminiferal stages: in Bandy, O. L., ed., Radiometric dating and paleontological zonation: Geological Society of America Special Paper 124, p. 91-129.

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. Geological Survey Bulletin, no. 1457-E, 31 p.

U. S. Geological Survey, 1980, Aeromagnetic Map of the Ventura Basin, Ventura and Los Angeles counties, California: U. S. Geological Survey, OFR 80-64.

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

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

Wilson, R. W., 1949, Rodents and lagomorphs of the upper Sespe: Carnegie Institute Washington, Publication no. 584, p. 51-65.

Yeats, R. S., 1964, Andesite sill at South Mountain oil field, Ventura County, California (abstr): Geological Society of America, Special Paper no. 76, p. 233.

Yeats, R. S., 1965, Pliocene seaknoll at South Mountain, Ventura Basin, California: American Association of Petroleum Geologists Bulletin, v. 49, no. 5, p. 526-546.

Yeats, R. S., 1968, Rifting and rafting in southern California borderland, in Dickinson, W. R., and Grantz, Arthur, eds., Proceedings of conference on geologic problems of San Andreas fault system: Stanford Univ. Pubs., Geological Sciences, v. 11, p. 307-322.

Yeats, R. S., 1976, Neogene tectonics of the Central Ventura Basin, California: in Fritsche, A., Ter Best, H., and Wornardt, W., eds., the Neogene Symposium: Pacific section, Society of Economic Paleontologists and Minerologists, San Francisco, California, p. 19-32.

Yeats, R. S., 1983a, Simi: A structural essay: in Squires, R. R. and Filewicz, M. V., eds., 1983, Cenozoic geology of the Simi Valley area, Southern California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 233-240.

Yeats, R. S., 1983b, Heavy oil accumulations in the Oxnard field: in Issacc, C. M., and Garrison, R. E., eds, Petroleum generation and occurrences in the Miocene Monterey Formation, California, Pacific Section, S.E.P.M., Fall field trip volume and guidebook, p. 85-98.

Yeats, R. S., 1983c, Large-Scale Quaternary detachments in Ventura basin, southern California: Journal of Geophysical Research, v. 88, no. B1, p. 569-583.

Yeats, R. S., Cole, M. R., Merschat, W. R., and Parsley, R. M., 1974, Poway Fan and Submarine Cone and Rifting of the inner Southern California Borderland: Geological Society of America Bulletin, v. 85, no. 2, p. 293-302.

Yeats, R. S., Butler, M. L., and Schlueter, J. C., 1977, Geology of the Central Santa Susana Fault Area, Ventura and Los Angeles Counties, California: United States Geological Survey Technical Report, no. 14-08-0001-15886, 29 p.

Yerkes, R. F., McCulloch, T. H., Schoellhamer, J. E., and Vedder, J. G., 1965, Geology of the Los Angeles basin California - an introduction: U.S. Geological Survey Professional Paper 420-A, 57 p.

Yerkes, R. F., and Campbell, R. H., 1979, Stratigraphic nomenclature of the central Santa Monica Mountains, Los Angeles County, California: United States Geological Survey Bulletin, no. 145-E, 31 p.