GEOLOGY OF THE TUNIS - PASTORIA CREEK AREA
KERN COUNTY, CALIFORNIA

Thesis

by

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TABLE OF CONTENTS

Manuscript Page

LIST OF ILLUSTRATIONS

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ABSTRACT

The geology of the Tunis-Pastoria Creek area, located approximately thirty miles southeast of Bakersfield, California, is rather simple from a regional standpoint. It more closely resembles the geology of the eastern edge of the San Joaquin Valley than that of the Coast Range province to the west. In the area mapped, pre-Tertiary crystalline rocks of the Tehachapi Mountains are overlain with a depositional contact by Tertiary sedimentary and volcanic rocks. These Tertiary rocks range in age from Middle Eocene to Lower Pliocene. Extensive terrace deposits and tilted alluvial fans of Quaternary age record the more recent history of this part of the San Joaquin Valley.

Structurally the area is characterized by strata that dip moderately to the northwest, and by two sets of faults, one trending roughly parallel and the other perpendicular to the strike of the beds. Movement along most of these faults is believed to be of the normal type. Folding is minor and limited primarily to phenomena associated with faulting. Structures have been complicated by repeated periods of uplift and subsidence that have given rise to numerous unconformities in the Tertiary section.

INTRODUCTION

Background of Investigation

This report and the accompanying geologic map have been prepared in partial fulfillment of the requirements for the Degree of Master of Science in Geology at the California Institute of Technology, Pasadena, California. The area was selected because it contains several moderately complex stratigraphic and structural problems. In as much as abundant subsurface information from nearby oil wells was available, it was hoped that this information in conjunction with detailed field studies would throw some light on these problems. The only published work on the area mapped in this investigation is that of H. W. Hoots (30)* which was of a reconnaissance nature. For a list of reports pertaining to geologic investigations of this general vicinity, the reader is referred to the bibliography.

Mapping by Hoots was done on an enlarged topographic base which had an original scale of 1:125,000. The field mapping in this investigation was done on a scale of approximately 1:20,000. Complete aerial photographic coverage of the area was available, thus allowing much greater detail and accuracy in mapping than that obtained by Hoots. At intervals from October, 1949 to April, 1950, approximately fifty days were spent on this project, thirty for field and the remainder for office work. It was

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* Numbers in Parentheses refer to references in bibliography.

possible to "walk out" almost all contacts in the area. Where concealed by a thick cover of soil or alluvial debris, the contacts were easily inferred because of the general simplicity of the geologic structure. In the northern part of the area outcrops are very scarce, and although structural relationships are somewhat obscure, formational contacts were mappable by means of soil changes and the character of residual detrital fragments in the surface mantle.

The geology was transferred from aerial photographs to a photographic mosaic with a scale of 2 inches to the mile, and from the mosaic to parts of the Pastoria Creek and Tejon Hills quadrangle maps which were the same scale. The Pastoria Creek quadrangle map, which covers most of the area studied in this investigation, was mapped topographically by means of photogrametric methods in 1943 by the United States Corps of Engineers. Because of the favorable topographic map and photographic coverage, the detail and accuracy attained by mapping on large scale aerial photographs was preserved in the transfer of geologic data to the base map.

Data from all oil wells in the immediate vicinity of the mapped area that have core descriptions and/or electric well logs were used for the determination of subsurface relationships of the formations. Only wells that have been referred to in the text of this report are numbered on the geologic map (Plate I), and as each well is cited for reference, the corresponding number is given in parentheses immediately following the name of the well. A list of these wells is included in the appendix at the end of the report.

Acknowledgments

The area mapped is part of the Tejon Ranch, and it is a pleasure to acknowledge the cooperation given by the ranch personel, especially L. H. Rochford and N. Flynn, who made access to the ranch property possible. Special acknowledgment also should be given to H. H. Van Akin and W. D. Shirey of Reserve Oil and Gas Company, who made available all subsurface data on oil wells in this vicinity. Facilities of the company field office also were put at the disposal of the author. Additional data from the firm of Oil Properties Consultants were made available through the courtesy of F. H. Bailly and H. M. Kilian.

Messrs. H. K. Armstrong and L. W. Richards, consulting geologists, spent considerable time discussing regional and subsurface relationships of the area with the author, and helped immeasurably in the preparation of this report. The writer also is indebted to the geological department of The Texas Company for their examination of the micro-paleontological samples collected, and for the reproduction of maps and sections included in this report. The author wishes to express his gratitude to Dr. Richard H. Jahns for his excellent instruction. The writer also is indebted to Dr. Jahns for his helpful criticism of the first draft of this manuscript.

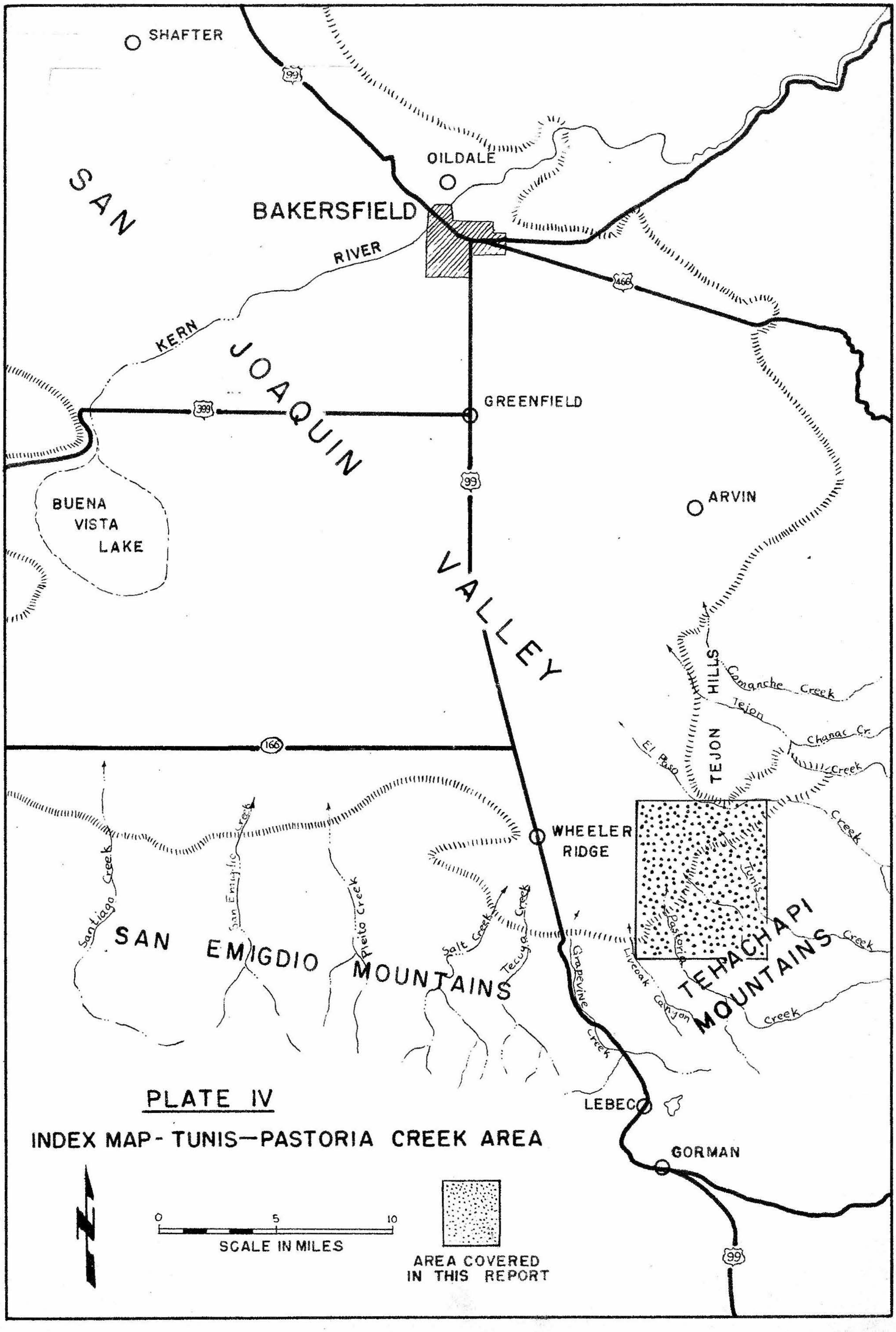

PLATE IV

INDEX MAP - TUNIS—PASTORIA CREEK AREA

Location and Physical Features

The area mapped in this investigation is located along the southeast edge of the San Joaquin Valley, approximately 30 miles in a south-southeast direction from Bakersfield, California (See Index Map, Plate IV). The center of the area is about 2 miles east of the northwest corner of T.10N., R.18 W., San Bernardino baseline and meridian. An area of approximately 15 square miles was mapped between Pastoria Creek and the eastern edge of the Tunis Creek fan. Of this area, approximately 5 square miles is covered with terrace gravel and tilted alluvial fan deposits; the remainder consists of Tertiary sedimentary and volcanic rocks and pre-Tertiary crystalline rocks.

The relief of most of the area is moderate, with elevations ranging from 800 feet to 1,800 feet; however, the Tehachapi Mountains, which are immediately adjacent to the area, rise above the foothills to an elevation of about 4,500 feet in a horizontal distance of 2 or 3 miles. The physiographic relationships along this bold scarp and in the foothill belt to the northwest are dominantly youthful. All canyons to the southeast are steep walled, and streams working headward by erosion, are dissecting the extensive terrace deposits of the foothill belt.

The only perennial stream in the area is Tunis Creek. Water from this creek has been diverted across the Tunis fan to Willow Creek, which drains into a reservoir to the north. The vegetation of the area consists almost entirely of grass and scattered oak trees. The complete lack of underbrush is in marked contrast to most hilly regions of Southern California.

COLUMNAR SECTION

PLATE V

ERA	PERIOD	EPOC	FORMATION	SYMBOL	SECTION	THICKNESS IN FEET	CHARACTER
CENOZOIC	QUATERNARY	RECENT	ALLUVIUM	Qal		0-300'	Soil, sand, and gravel
			TERRACE DEPOSITS: POST-TUNIS	Qt 3		0-50'	Boulder and cobble gravel
			TERRACE DEPOSITS: TUNIS	Qt 2		0-200'	
			TERRACE DEPOSITS: PRE-TUNIS	Qt 1		0-230'	
		Pleistocene(?)					
	TERTIARY	LOWER PLIOCENE	CHANAC	Tc		550-1250'	Continental Tan gritty mudstones, sandstones, conglomerates and claystones Green claystones and coarse arkosic sandstones
		UPPER MIOCENE	SANTA MARGARITA	Tsm		300-650'	Marine White, coarse, pebbly sandstone, conglomerates and minor silts
			PULVINULINELLA GYROIDINAFORMIS ZONE	Tpz		0-600'	Marine Silty shales and fine sandstones--subsurface only
		MIDDLE MIOCENE	VALVULINERIA CALIFORNICA ZONE	Tvz	? ? ?	0-400'	Marine Silty shales and fine sandstones--primarily subsurface
			TEMBLOR	Ttmb		0-1100'	Marine & Continental Coarse, gritty sandstones and boulder conglomerates
		LOWER-MIDDLE(?) MIOCENE	VOLCANIC ROCKS	Tv Ta	Disconformity	0-1500'	Tv-basalt and andesite flows and minor intrusions Conglomeratic marine sediments to the east Ta-dacite flows and associated pyroclastics
			TECUYA	Ttc		0-1000'	Marine & Continental Conglomerates, coarse arkosic sandstones, fine sandstones and silts
		MIDDLE EOCENE	TEJON	Ttj		0-610'	Marine Tan, fine sandstones, silty sandstones, conglomerate, fossil and calcareous reefs
PRE-TERTIRY			CRYATALLINE ROCKS	PTc			Granodiorite, gneiss, schist, quartzite, and coarsely crystalline marble

STRATIGRAPHY

The oldest rocks exposed in the mapped area consist of pre-Tertiary igneous and metamorphic rocks. These crystalline rocks are overlain by a section of sedimentary and volcanic rocks approximately 5500 feet thick. Associated with the volcanic flows are a few minor sills and dikes of basic composition. The age of these younger rocks ranges from Middle Eocene to Recent.

Pre-Tertiary Crystalline Rocks

General Features

The core of the Tehachapi Mountains consists primarily of granodiorite, however, intrusive rocks that range in composition from granite to gabbro also are present. The crystalline rocks in the southeast part of the area mapped are dominantly banded gneisses and dark-colored hornblendic schists that are cut by numerous pegmatitic dikes. These dikes are several feet thick, and outcrop for a maximum horizontal distance of 300 to 400 feet. They are coarse grained, and consist of quartz and microcline with scattered books of muscovite as large as one inch in diameter. Associated with these crystalline rocks are local beds of quartzite and coarsely crystalline marble. Several miles to the east an intrusion contains euhedral but rather impure garnet crystals, some of which are the size of a man's fist.

According to Hoots (30) the granitic core of the Tehachapi Mountains is connected at the surface with the Sierra Nevada batholith, which is reported to be Upper

Jurassic in age (N. L. Taliaferro 42). Although the intrusive rocks of the Tehachapi Mountains are connected with those of the Sierra Nevada batholith, time relationships have not been worked out sufficiently to date the intrusions in this vicinity more precisely than Mid-Mesozoic. The oldest unmetamorphosed sediments in the southeast part of the San Joaquin Valley are Middle Eocene in age. This investigation deals primarily with the Tertiary rocks and their structural features, therefore no detailed geologic work has been done on these older crystalline rocks.

Tejon Formation

General features

The Tejon formation in the area mapped lies with depositional contact on the crystalline rocks, and is exposed as a narrow wedge of fine grained marine sediments that extends from Pastoria Creek northeastward to the Tunis fault (Plate I). It is overlain unconformably by the Miocene Tecuya formation in the vicinity of Pastoria Creek. In general the Tejon sediments form valleys and drainage divides that lie parallel to the mountain front, and many steep-walled gullies give excellent exposures of the formation. In contrast, most of the gentle slopes and valley floors are covered with soil and alluvial debris.

A 610 foot section of Tejon beds was measured just east of Pastoria Creek. Here the formation consists of several distinct lithologic units that are recognizable throughout the entire mapped area. The contact between the

Tejon formation and the crystalline rocks is overlain by a basal conglomerate that ranges in thickness from 4 to 12 feet. This conglomerate is poorly indurated and consists of angular to subangular rock fragments of schist, gneiss, and granitic rocks derived from adjacent highlands of crystalline rocks. The fragments range in size from granules to boulders about 3 feet in diameter. These coarse clastic rocks contain a matrix of poorly sorted granitic sand, which on casual observation could easily be mistaken for deeply weathered gneissic rock. This basal conglomerate grades upward into a thin sandstone unit of variable thickness. The sandstone is soft, friable, and argillaceous, but is nonetheless gritty, and is composed primarily of quartz and feldspar grains. It is medium-to coarse-grained, dominantly white to gray in color, and poorly sorted; the larger grains are frosted and well rounded. The marine origin of these beds is established by a few scattered casts and molds of marine mollusks. To the northeast this member seems to thicken somewhat and becomes conglomeratic.

Overlying this unit and separated from it by a transition zone several feet thick is the third member of the Tejon formation. At Pastoria Creek this member is approximately 270 feet thick, and consists of massive beds of fine-grained to silty sandstones. These are distinctively a uniform light tan in color at the outcrop, with a few gray streaks. True clay shales are almost non-existent in this member. Individual beds are characteristically massive, and range in thickness from a few inches to about 8 feet. Outcrops weather in a blocky to irregular manner.

Although quartz is the major constituent of these sediments, both light and dark colored feldspars are abundant as well. Magnetite or ilmenite, bleached biotite, and sericite also are present in variable but minor amounts. The cementing material is siliceous and argillaceous. Rust-colored clusters of sand grains 0.5 to 1.0 millimeters in diameter are common; with careful breaking several of these proved to be hollow and to have definite form. Most of the clusters undoubtedly are the remains of foraminifera from which the calcareous material has been leached and partially replaced by iron oxides. The entire formation contains abundant casts and molds of mollusks in which this same alteration has taken place but to a lesser degree. Subsurface parts of the formation contain appreciable amounts of pyrite and glauconite, some of which may have been the source of the iron associated with this replacement phenomenon.

Above these massive sandstones and siltstones is a section of sediments approximately 330 feet thick which contains numerous calcareous beds. The calcareous beds, which range in thickness from 6 to 18 inches and are stratigraphically 10 to 15 feet apart, stand out as narrow ridges on the steeper hillsides. They vary in composition from calcareous sand and silt to dense sandy limestone and marl, and are tan in color. Some are rich in fossils, and it is primarily from such beds that the most abundant and best preserved specimens in the fauna of the Tejon formation have been obtained. The best outcrops of these fossiliferous beds are present about 1 3/4 miles northeast of Pastoria Creek. The sediments between those calcareous beds consist of typical tan-colored sandstones and siltstones similar to those described above, but they are somewhat thinner bedded and contain a few thin clay shales and silty shales. To the east this horizon also becomes somewhat coarser and contains a few thin conglomeratic beds. Granitic boulders are scattered through the fine-grained sandstones and siltstones in this region, and one such boulder, about 8 feet long and 3 feet thick, is associated with a thin conglomeratic lens less than 2 feet thick.

The Tejon formation was named for old Fort Tejon, which is in the Canada de las Uvas (Grapevine Canyon), and was first described in 1853 by W. P. Blake, a geologist for the Pacific Railroad Survey. He collected a single rock specimen that contained about 13 species of mollusks, which were subsequently identified by T. A. Conrad (55) as Eocene in age. Within a few years W. M. Gabb identified a series of fossils from the Tejon beds as late Cretaceous (Gabb, in Whitney, J. D. 68), and a bitter controversey arose between these two men. Subsequent work has demonstrated the correctness of Conrad's original identification of the beds as Eocene.

The unusually abundant and well preserved faunal assemblage in the Tejon formation has led to extensive paleontologic investigation of the beds, and a considerable amount of geologic literature has been devoted to descriptions of this work. The most comprehensive paleontological studies have been made by R. E. Dickerson (15), Anderson and Hanna (25), and Clark and Vokes (36). H. W. Hoots (30) described the aerial extent and general lithologic features of the formation in his paper on the geology and oil resources along the southern border of the San Joaquin Valley. The most recent work dealing with the type Tejon beds was done by J. G. Marks (43), who mapped the beds from Pastoria Creek to Tecuya Creek and was able to distinguish four lithologically distinct members of the formation. Although most investigators consider the entire Tejon formation to be Upper Eocene in age, Marks assigns his two lowest members, the Uvas conglomerate and Liveoak section, to the uppermost Middle Eocene, and his two upper members, the Meteralla sandstone and Reed Canyon siltstone, to the Upper Eocene.

A fauna typical of the part of the formation mapped in this investigation has been identified from two fossil localities of the California Academy of Science.

C.A.S. Coll.,Loc. 815. Basal beds of the Tejon formation on the west side of Pastoria Creek east of Grapevine Canyon

Glycymeris sagittata (Gabb)
Spondylus carlosensis Anderson
Macrocallista andersoni Dickerson
Ostrea sp. undt.
Crassatellites uvasanus (Conrad)
Mytilus humerus Conrad
Barbatia sp. of B. morsei Gabb
Crepidula pileum (Gabb)
Calyptraea excentrica (Gabb)

C.A.S. Coll., Loc. 816. 600 feet above the base of the Tejon group, on east side of Pastoria Creek, east of Grapevine Canyon

Pitaria californiana (Conrad)
Mytilus humerus Conrad
Brackydontes ornatus (Gabb)

Teredo sp. undt. (in fossil wood)
Turritella sargeanti A & H n.sp.
Whitneya ficus Gabb
Spisula bisculpturata A & H n. sp.
Venericardia ~~Veneracrdia~~ hornii (Gabb)
Crepidula pileum (Gabb)
Amauropsis alveata (Conrad)
Dendrophyllia tejonensis Nomland
Cardium breweri Gabb

Anderson and Hanna believed that the beds from which this faunal assemblage came represent earlier horizons of the Tejon group at its type locality. On the other hand, C. W. Merriam (in Clark & Vokes 36), in preparing his monograph on the Turritellas of western North America, noted that T. uvasana Conrad (Sensu Stricto) is limited to the lower part of the Tejon formation at the type locality and that T. uvasana subsp. sargeanti Anderson and Hanna is characteristic of the upper part of that series. On the basis of these paleontological data and the lithologic characteristics observed in Liveoak Canyon, the Tejon formation east of Pastoria Creek is considered to be equivalent to the upper part of Mark's Liveoak member (43), which he considers to be uppermost Middle Eocene in age. These beds correspond to the Upper Tejon stage in the Turritella uvasana sargeanti zone, according to Clark and Vokes (36).

Subsurface relations

Subsurface relationships of the Tejon formation in this part of the San Joaquin Valley have not been determined because few oil wells have penetrated this unit. To the writer's knowledge no surface evidence of petroleum has been found in the Tejon formation. The Richfield Tejon

Ranch #1 well (1) in Sec. 2 10N-19W is the only well to reach marine rocks of Eocene age in this vicinity. The top of the Eocene section was found at 9698 (-8654) feet, and approximately 1200 feet was penetrated before abandonment of the well at a depth of 10,940 feet. Core descriptions of these beds show that they are almost identical lithologically to outcrop samples of the Tejon formation. Dips found in this formation were between 25° and 30°. Pyrite, glauconite, and carbonaceous material were present in many of the cores examined. Well preserved fossils also were noted.

The penetrated Eocene section was extensively cored, but no shows of oil or gas were reported. Although to date no oil or gas has been found in this vicinity in the Eocene beds, shows were reported in the basal Tecuya beds of the Western Gulf's Tejon #1 well (10). This indicates that some oil might be expected in the Tejon formation between the extension of the Tunis fault and the Chanac Hills. It is believed that this formation is truncated by overlying Tecuya beds in the vicinity of these hills.

In 1947 the Western Gulf Oil Company drilled the Tejon Ranch #1 well (10) in Sec. 29 11N-18W, and at a depth of 4010 feet penetrated a series of non-marine beds distinctly different in lithology and electric log characteristics from the overlying Tecuya beds. About 220 feet of these sediments was penetrated before the well was abandoned.

This interval consisted of alternating massive dark green claystones, clayey siltstones, and green, gritty sandstones with clayey matrixes. Mottled-brown or brick-red oxidized streaks and scattered carbonaceous material also were present.

These sediments correspond in lithology to the Walker formation of the oil fields north and east of Bakersfield, California. The Walker beds have been interpreted by various geologists as the probable land-laid equivalent of marine beds that range in age from Eocene to Middle Miocene. The formation has a widespread distribution in the Bakersfield region, and attains a maximum recorded thickness of approximately 1400 feet in the Round Mountain oil field. It lies directly on much older crystalline rocks, and is not exposed at the surface. To the east it is overlapped by younger formations.

On the basis of lithology the green siltstones and claystones in the Western Gulf Tejon #1 well (10) were reported as Walker. These beds may be a land-laid facies of the Tejon formation; however, it is felt that they probably represent a continental phase of the Tecuya formation.

Tecuya Formation

General features

Overlying the Tejon formation with a slight angular unconformity is a series of alternating continental and marine beds, which is in turn overlain by and interlayered with volcanic flows and associated pyroclastic rocks. These sedimentary beds have been referred to as Tecuya or or Vaqueros by previous workers, and the local name Tecuya has been retained in the present investigation. The thickness of the Tecuya formation varies considerably in the area mapped, owing to over-lapping and interfingering relationships to the northeast. The section is thickest just east of Pastoria Creek, where 1090 feet of sediments is present between the Tejon formation and the base of the volcanic flows. It thins to approximately 450 feet just west of the Tunis fault. As in the Tejon formation, most of this thinning is due to the pinching out of members at the bottom of the section. Northeast of the Tunis fault the Tecuya formation lies directly on crystalline rocks. Here the relief of the erosion surface at Tecuya time was about 25 to 50 feet. Eastward volcanic rocks lie directly on the crystalline rocks, and between this point and Tunis Creek the volcanic flows are interlayered with sedimentary rocks. A short distance east of Tunis Creek the entire volcanic section pinches out.

The Tecuya formation as exposed between Pastoria and Tunis Creeks can be divided into three members. The lowest of these is conglomeratic, and at its base consists primarily of remarkably well rounded quartzite cobbles. These are about 3 inches in average diameter, are very smooth, and are characterized by abundant crescentic percussion marks. They are dominantly pink or buff in color, and show moderate banding. Small, well rounded pebbles of black chert and white quartz also are common. These pebbles and cobbles are set in a friable, medium-to coarse-grained quartzose sand. Undoubtedly they were derived from the adjacent metamorphic rocks of the crystalline highlands, and the extreme wear they show probably was caused by extensive wave action. Owing to the resistant nature of these cobbles, they are present as secondarily derived clasts throughout much of the overlying sedimentary section.

Upward this conglomeratic member becomes varied in its composition. It contains scattered, coarse-grained, granitic boulders as large as 4 feet in diameter, angular to subangular fragments of gneiss, chlorite and muscovite schist, and volcanic rocks. In general the matrix is much more arkosic and in places contains considerable amounts of biotite. The lower part of this member is distinctly marine and grades upward into sediments suggestive of a non-marine environment. It may represent a local regressive offlap condition in this vicinity. Although irregular in thickness and distribution, this member extends a short distance beyond the Tunis fault, where it is overlapped by the second member of the formation.

The second member is best developed just east of the Tunis fault, where it consists of massive beds of white, medium-to fine-grained marine sandstone several feet thick. These beds lie directly on crystalline rocks at this point, and near their base are gritty or conglomeratic. Associated with these marine sandstones are several thin cobble conglomerates which show particularly good sorting. Although evidence of plant remains were found in the fine-grained portion of this member, no diagnostic fossils were observed.

To the west this member loses its distinct marine characteristics and, although remaining dominantly fine-grained, it becomes arkosic and richer in clayey constituents.

The third and uppermost member of the Tecuya formation is conglomeratic, much like the upper part of the lowest member. It consists of large granitic boulders together with cobbles of varied composition contained in a matrix of pebbly arkosic sand. The sediments east of the point where the volcanic flows rest directly on crystalline rocks have been included in this uppermost member. These sediments are conglomeratic, and in places the matrix consists of volcanic ash. It is from an ashy bed in this member that marine fauna have been reported. Parts of this member are marine, but much of it may be continental in origin.

The exact thicknesses of these members cannot be determined accurately because of the gradational nature of the lithologic changes; however, at Pastoria Creek the approximate thicknesses of the lower, middle, and upper members are 500, 330, and 260 feet, respectively. The relationships of these thicknesses vary considerably to the northeast. The dominant structural features of this formation are its marked thinning to the northeast and its distinct marine characteristics east of the Tunis fault.

Both vertebrate and invertebrate remains have been found in the vicinity of Tecuya Creek, which is approximately 2 miles west of Grapevine Canyon. According to Stock (20 & 32), mammalian remains from the lower beds of this formation comprise several genera, and indicate a

Lower Miocene age. Clark (21) has stated that the Tecuya beds interfinger with marine Vaqueros in this general vicinity. Marks (43), in his investigation of the Tejon formation, found the following fauna in the lower 100 feet of the Tecuya beds: Potamides sp. nov., Crassatella sp., and Macoma cf. nasuta. Clark indicated that the latter species occurs in the Vaqueros formation and that the Tecuya beds were more likely Lower Miocene than Upper Oligocene.

The red and green siltstones of the lower Tecuya beds, which contain the known faunal assemblage of that formation in its type locality, are not present east of Pastoria Creek. Examination of all outcrops in this series of sediments between the base of the volcanic rocks and the top of the Tejon formation in the area mapped failed to disclose any information as to its age. To the northeast the volcanic rocks pinch out and interfinger with sedimentary deposits in a manner shown diagramatically in Plate II. These beds appear to be related both lithologically and structurally to the Tecuya sediments, which lie below the volcanic rocks to the west. Micropaleontological samples were taken from the sediments interlayered with volcanic flows by the author and geologists from Standard Oil Company. No diagnostic organic remains were found; however, H. K. Armstrong (verbal communication) has reported Valvulineria californica from this horizon. This would date the volcanic rocks and associated sediments as Middle Miocene, Luisian stage (Kleinpell, 36). On the basis of foraminifera found in marine sediments associated with these volcanic rocks in the Tejon oil field, G. C. Ferguson (48) has placed them in the Uvigerinella obesa var. impolita zone of the San Joaquin Valley, which is in Kleinpell's Lower Miocene, Saucesian stage. It is not known whether this age determination was made on the basis of a faunal assemblage or on the occurrence of the type species. This is important because Uvigerinella obesa var. impolita in this part of the valley is found scattered throughout the Middle Miocene sediments and has been observed as high as the top of the Valvulineria californica zone. On the basis of stratigraphic and structural relationships and available paleontological data, this formation as well as the overlying volcanic rocks can be dated only as Lower or Middle (?) Miocene in age.

Subsurface relations

Very few oil wells have penetrated the Tecuya formation, so that only its general subsurface relationships are known. Richfield's Tejon Ranch #1 well (1) penetrated 3,250 feet of sediments between the base of the volcanic rocks and the top of the Eocene beds. These sediments have a dip of 30°, and hence a true thickness of approximately 2,810 feet. They comprise considerable thicknesses of sandstone that are separated by shale and siltstone intervals as much as 200 feet thick. Very few cores were taken in this interval, and no shows of oil or gas were reported.

Approximately 1,100 feet of Tecuya beds are present in the Western Gulf Tejon Ranch #1 well (10), and almost the entire section was cored. The bulk of the sediments consists of fine-to medium-grained micaceous silty marine sandstones with shales and conglomeratic beds. Although mollusk shells, foraminifera, and some fish scales were present in the cores, no age determination was reported. Several thin, oil-stained sands were cored near the base of this formation, and gas odors were observed higher in the section. Richfield's Tejon Ranch #2 well (9), sec. 19, 11N-18W, penetrated about 390 feet of Tecuya beds before drilling into crystalline rocks. This thin section presumably is due to a high erosional remnant on the crystalline - sedimentary surface.

Volcanic Rocks

General features

A thick series of volcanic flows and associated pyroclastic rocks overlies the Tecuya formation with a slight disconformity and interfingers with it to the east. The volcanic rocks are fairly resistant to erosion, forming rather steep hills. In outcrop the rocks are most commonly dark reddish brown to black in color, and weather to a dark red-brown soil. These volcanic rocks are primarily olivene basalt and andesite with minor dacite. Their aggregate thickness varies considerably, with a maximum in the area mapped of approximately 1,500 feet midway between the Tunis fault and Tunis Creek. The youngest series of flows is truncated by Valvulineria californica (?) siltstones and Santa Margarita sandstones near the western edge of the Tunis fan. The maximum eastern extent of the volcanic rocks at the surface is marked by a small outcrop east of the Tunis fan. From subsurface informaton the eastern limit of the volcanic rocks extends almost due north from this point and swings to the northwest near the Tejon Hills. The volcanic rocks thin rapidly westward toward the Tunis fault, where they are approximately 830 feet thick. Between here and Pastoria Creek relationships are masked somewhat by alluvium and terrace deposits, but about midway between these points the boulder beds of the overlying Temblor formation lie in direct contact upon Tecuya beds, marking the low point in an old erosional channel that evidently was cut completely through the volcanic rocks.

The Tecuya sediments usually are baked by the overlying flows. A zone of flow breccia, as much as 10 feet thick, is present in many places at the base of the volcanic rocks, and contains mixed volcanic debris and sedimentary material including granitic boulders several feet in diameter. The overlying series of volcanic rocks consists almost entirely of flows that range in thickness from a few feet up to 40 or 50 feet. A very small proportion of the volcanic flows is massive, and the bulk of them contain blocky to irregular structures. Scoriaceous material is abundant, and in most specimens shows evidence of flowage. In places the scoriaceous material is amygdaliodal, with cavity fillings of quartz, calcite, or zeolites. Poorly developed elipsoidal structure and intercalated marine sediments suggest that parts of the section may have been poured out under water. A considerable amount of flow breccia and minor pyroclastic material is present between individual flows in many places.

Several feet above the base of the volcanic flows is a series of dacitic flows and pyroclastic rocks that extends eastward from Pastoria Creek to points a short distance beyond the Tunis fault. The dacite is pink in color, contains lath-like phenocrysts of plagioclase in an aphanitic groundmass, and most specimens exhibit a flow structure similar to that in many so-called "taffy rhyolites". Associated with these dacitic flows is an agglomeratic rock that consists of angular dacite fragments in a light-colored ashy matrix. Because this series is light in color and very resistant to erosion, it stands out noticeably both in relief and color among the dark-colored volcanic rocks, as shown in Plates VIII and XI. Eastward this unit pinches out, and beyond this point a conglomeratic bed is present at this horizon.

A large travertine vein is present east of the Tunis fault, and it trends for at least half a mile in a north-south direction. It ranges from 1 to 12 feet in thickness, and consists of white and amber layers, varying in thickness from 6 to 12 inches. In places these layers are separated by thin slices of basalt. Much of the travertine is beautifully banded and is marked by radiating structures. No apparent dislocation was observed along the line of this vein, and it probably represents a fracture that was filled with travertine during the dying stages of the volcanism. A similar, but much shorter zone, is present to the south.

The notable lack of pyroclastic debris in the volcanic rocks suggests that they may have originated in large part from fissure-type eruptions. A short distance west of the

Tunis fault a sharp gully has been cut through the volcanic flows, exposing a feeder dike 10 to 15 feet wide that must have contributed lava to one or more of the upper flows (See Plate VII). This dike consists of dense, blocky basalt that is very uniform in composition and texture. It contains some granitic rock fragments, presumably carried up from below. The walls of the dike are flanked by zones of coarse, conglomeratic sandstone that has been so thoroughly impregnated with volcanic fluids that many specimens could be easily mistaken for granitic igneous rock. These zones range from 18 inches to 3 feet in width, and are more resistant to erosion than either the surrounding sediments or the enclosed volcanic rock. The trend of this dike is N. 25° W., and its dip is approximately 80° to the northeast.

Associated with these volcanic rocks in this vicinity is a series of sills. The larges of these sills lies immediately southeast of the feeder dike described above, and forms the crest of the ridge shown in Plate XII. This sill occurs in the Tecuya beds just above the top of the Tejon formation. To the east basaltic material has been intruded at this same horizon, as well as along the contact between crystalline rocks and the overlying Tejon formation. Known intrusive bodies associated with the volcanic rocks are limited to this locality; however, several of the units higher in the volcanic section may be sills rather than surface flows.

The age relationships of these volcanic rocks have been discussed in connection with the Tecuya formation.

Subsurface relations

The distribution of the volcanic rocks is very widespread, and in outcrop they occur intermittently at this general horizon from Tunis Creek westward for a distance of about 20 miles to Plieto Creek. Drilling has shown that they underlie the entire Tejon oil field, and probably extend several miles to the north. The following wells in the vicinity of the mapped area penetrated a complete section of volcanic rocks:

Well No.	Location	Top of basalt	Approx. thickness (Corrected for dip)
Richfield #1 (1)	Sec. 2-10N-19W	5452 feet	865 feet
Ohio B-1 (3)	Sec. 36-11N-19W	4313 feet	830 feet
Richfield #2 (9)	Sec. 19-11N-18W	3628 feet	805 feet
Western Gulf #1 (10)	Sec. 29-11N-18W	2990 feet	470 feet
Richfield B-1 (11)	Sec. 28-11N-18W	1077 feet	260 feet

Several other wells were bottomed in basalt.

The available data show a regional dip of approximately 20° in a general west-northwest direction, but steeper dips are usually recorded from cores. The Western Gulf Tejon Ranch #1 well (10) penetrated parts of the volcanic section which were saturated with oil, however, no production was obtained.

Temblor Formation

General features

A series of alternating continental and marine sediments, similar in many respects to the underlying Tecuya beds, overlies the volcanic rocks with a marked unconformity. These beds were mapped by Hoots (30) as the Vaqueros formation, however, they contain a fauna similar to that of the Temblor formation. The Temblor sediments in this area crop out from a point about one mile west of the Tunis fault northeastward to the edge of the Tunis fan, where it is overlapped unconformably by the Valvulineria californica (?) siltstones and the Santa Margarita formation. To the west it is covered by alluvium and terrace deposits. A maximum thickness of 1,100 feet is preserved on the downthrown eastern side of the Tunis fault, which is pre-Santa Margarita (pre-Upper Miocene) in age.

The Temblor formation consists of three members, which show much inter-gradation and interfingering. The lowest member is a boulder conglomerate with associated sandstones, and in lithology resembles the upper member of the Tecuya formation. The rock types in this conglomerate consist of large boulders of quartz-microcline pegmatite with small amounts of muscovite, quartz-rich boulders and cobbles of granitic and monzonitic composition, well rounded quartz and quartzite cobbles, boulders of andesite derived from the underlying flows, and a few boulders of dark-colored, banded gneiss and schist. One rock type is present in the Temblor formation that is lacking in the Tecuya formation. A white rhyolite with large euhedral quartz phenocrysts and small hexagonal books of black biotite set in an aphanitic groundmass is abundant in all conglomeratic phases from the base of the Temblor formation up into the Santa Margarita formation. Almost all specimens show the marked "taffy" flow structure so typical of many rhyolites. This rock forms extraordinarily large blocks, and yields the largest boulders found in the conglomerate beds (Plate X). The source of these rhyolite clasts is not known; however, they must have been extruded nearby, either south or east of the area, during the very last stages of the volcanism. The fact that the rocks of both this formation and the Tecuya formation are dominantly light colored is a great help in distinguishing them from more recent terrace gravels, in which the boulders are dark in color.

The surface on which the lowest member lies is erosional, and locally exhibits considerable relief. The member is thickest to the west, and reaches its maximum development on the west side of Pastoria Creek just outside of the area mapped. It thins to the northeast, pinching out about half way between the Tunis fault and the edge of the Tunis fan.

The middle member of the Temblor formation is dominantly marine, and consists primarily of white to buff, gritty, arkosic sandstones. It is recognizable east of the Tunis fault only, and to the northeast it lies directly on the volcanic rocks. Here it contains streaks that are extremely well cemented with calcareous material, and in places forms haystack-like blocks that rise several feet above the surrounding slopes. The surfaces of these blocks are commonly fretted, exhibiting a small-scale cavernous weathering (Plate IX). Immediately east of the Tunis fault, several cobbles and large boulders of very coarsely crystalline marble were found incorporated in the sediments, and probably was a contributing factor in the local cementation of these sandstones. Calcium also may have been supplied by circulating ground water derived from volcanic springs similar to the one that formed the large travertine vein.

The occurrence of two clastic dikes was observed along the contact between the middle member of the Temblor formation and the underlying volcanic rocks. The outcrop length of the largest dike is about 90 feet, it ranges from 6 to 15 feet in width, and stands 6 to 8 feet above the surrounding volcanic rocks. It trends N. 40° W. and is almost vertical. The material of the dike is typical of the middle member, and is a buff, massive, gritty sandstone composed primarily of angular quartz grains with feldspar, clay and some biotite present. It is very well cemented with calcareous material, and weathers out in large joint blocks with moderately fretted surfaces. This clastic dike, as well as the one to the west, are merely fissures or crevasses in the volcanic rocks which have been filled with the overlying sediments.

The upper member of the Temblor formation also crops out east of the Tunis fault only. It is a boulder conglomerate, like the lowest member in composition, and forms the bouldery slopes shown in Plate X. The Santa Margarita formation overlies this member with pronounced angularity, and truncates it about one mile northeast of the Tunis fault. To the west this member is covered by extensive terrace deposits.

Only the lowest member is exposed west of the Tunis fault, therefore it is impossible to draw any general conclusion as to the environmental trends of the Temblor formation. However, the middle member is entirely marine and appears to increase in development to the east, paralleling the conditions that must have existed in the underlying Tecuya formation. These relationships and the abrupt thickening of the volcanic rocks seem to point toward some form of tectonic control in this region, and could be explained either by intermittent local down-warping during accumulation of the Tecuya, volcanic, and Temblor rocks or perhaps by early movement along the Tunis fault.

A Valvulineria californica fauna has been reported from the basal beds of this series, which would indicate a Middle Miocene age, Luisian stage. Fragments of mollusk shells, including Turritella, Lucina, Pectin, and Osterea, were found in a very hard calcareous sandstone just west of the Tunis fan. A complete section of one Turritella resembles very closely the species ocoyana, which is of Middle Miocene Temblor age. On the basis of these data, the formation is considered Middle Miocene in age.

Subsurface relations

Although the Temblor formation has been penetrated in a number of oil wells, not much is known about its detailed subsurface relationships. Difficulty arises in recognizing the top of the formation. Valleyward the formation is an alternating series of marine and non-marine beds with characteristics that change rapidly both laterally and vertically. The inclusion of finer-grained sections in the formation also adds to the problem. The top is usually placed either at the point where continental type sediments are encountered in drilling or at the upper limit of the coarse-grained sediments below the Valvulineria californica shales. In most wells this section contains no diagnostic fauna. No oil or gas shows of any consequence have been reported from the Temblor formation; consequently most wells are bottomed before reaching it. In the vicinity of the Tejon oil field the probable equivalent of the Temblor formation is approximately 720 feet thick.

Valvulineria californica Zone*

Overlying the Temblor formation with a questionable unconformity is a series of silty shales with associated lenticular sandstones that contains an abundant faunal assemblage of Middle Miocene age, Luisian stage. This formation underlies at least a portion of the northern part of the area, and may not crop outat the surface. It is overlapped unconformably by the Santa Margarita formation. It is from sandstones in this interval that the newly discovered Tunis Creek oil field is producing and around which the recent activity in the Tejon oil field has centered.

Lithologically the Valv. zone is almost wholly a monotonous series of rudely bedded, gray-brown, silty, micaceous shale. A few fine-to coarse-grained lenticular sandstones and scattered thin bentonitic streaks are commonly present in this zone. Almost all well cores

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* This zone will be referred to subsequently as the Valv. zone.

examined contained abundant organic material consisting primarily of foraminifera with a few well preserved mega-fossils, fish scales, and carbonized plant material. A thickness of 400 to 500 feet can be considered a maximum in the area mapped. The absence of Valv. shale in the Slosson Reservoir Hill #1, well (4), Sec. 32,11N-18W, indicates that all or most of the Valv. zone may be missing southeast of this point, unless repeated by the Willows fault.

A thin section of silty sandstones and shales is present at the base of the Santa Margarita formation near the edge of the Tunis fan. The exposed interval is not more than 20 feet thick, and consists primarily of fine-grained, silty, gray sandstones with beds of purple to dark gray shale. Several micro-paleontological samples were taken from these siltstones, and all proved to be barren, as were samples taken by Standard Oil Company. Valvulineria californica, however, have been reported from the horizon (H.K. Armstrong, verbal communication). Near the top of this section is a horizon containing large "cannon-ball" concretions of calcareous silt and sand. Several of these were broken open, but none contained any evidence of organic material. Structurally these silty sandstones and shales appear to be more closely related to the overlying Santa Margarita formation than to the underlying truncated Temblor formation and volcanic rocks. If this thin section is correlative with the Valv. zone to the north of the Springs fault, a thick wedge of Valv. shale and sandstones may be present southeast of the Willows fault.

The Valv. zone is upper Middle Miocene in age, Luisian stage, and is equivalent to the Round Mountain silt of the oil fields near Bakersfield, California. The most complete description of the faunal assemblage was obtained from the Drilling and Production #33 well (5), Sec. 32,11N-18W. The paleontological data, as reported by R. Stanley Beck, are shown on the following page. In addition to the species reported in this well, Siphogenerina collomi, Hemi cristellaria beali, and Valvulineria robusta have been found in the Valv. zone.

Pulvinulinella gyroidinaformis Zone*

Overlying the Valv. zone in this part of the San Joaquin Valley is a section of shales and sandstones of Upper Miocene age, Lower Mohnian stage. Lithologically this zone is identical to the underlying Valv. zone, and can be separated from it on the basis of paleontological data only. In places the Pulv. zone contains numerous sandstone beds in its upper part, making very uncertain the determination of the base of the Santa Margarita formation by means of electric well logs alone. This zone has a maximum thickness of about 200 feet beneath the area mapped, and it is overlapped by the Santa Margarita formation in the vicinity of the Tunis Creek oil field. No surface exposures are present in the area mapped.

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* This zone will be referred to subsequently as the Pulv. zone.

Drilling and Production #33-32 well (5)
Micro-paleontological data reported by R. Stanley Beck

	900	Base Santa Margarita formation
Upper Miocene L. Mohnian stage	1,000	Barren
Pulvinulinella gyroidinaformis zone	1,100	Pulv. gyroidinaformis-few Nonion costiferum-few
Middle Miocene Luisian stage Valvulineria californica zone Sensu lato	1,200	Bolivina advena striatella-few Uvigerina cf.obesa impolita-few* Uvigerina cf.obesa impolita-c Valv. miocenica-c.
Middle Miocene Luisian stage Valvulineria californica zone Sensu stricto	1,300	Anomalina salinasensis-ab Valv. miocenica-few Bolivina advena striatella-ab Pullenia miocenica-few Valv. californica-ab Valv. californica-ab Siphogenerina nuciformis-few Cassidulina crassa-c
	1,400	Fish remains only
	1,500	Siphogenerina branneri Top Temblor formation (?)
	1,600	
	T.D. 1693	

*(Often occurs in assemblages referred to as the Reserve or pseudo-Saucesian facies)

This zone contains a faunal assemblage typical of the <u>Pulvinulinella gyroidinaformis</u> foraminiferal zone, and is equivalent to the Lower Fruitvale shale in the oil fields on the east side of the valley. In addition to the species identified in the Drilling and Production #33 well (5), <u>Bolivina modeloensis</u> and <u>Uvigerina hootsi</u> also have been reported from this interval.

Santa Margarita Formation

General features

The Santa Margarita formation overlies the Pulv. zone with an angular unconformity and truncates successively older beds to the south and east. The Santa Margarita formation crops out over a limited area between the gravels of the Tunis fan to the east and terrace gravels of younger age to the west. Owing to its uniform lithology, the Santa Margarita forms smooth, rounded hills of minor relief (See Plates X and XVIII). Almost all slopes have a deep soil cover that results in a virtual lack of exposures. The only exceptions are the steep western scarp of the Tunis fan and a few sharp "V"-shaped gulleys formed by ground-water sapping. Conglomeratic beds control the localization of the hills in many places, and leave a residual accumulation of pebbles and small cobbles on the highest points of these hills.

Lithologically the Santa Margarita formation is very uniform in both composition and texture, and can be described as a massive, coarse-grained, gritty sandstone that is white in outcrop and gray or blue-gray in well cores. Although most specimens are very friable, some calcareous streaks have been found in well cores to the north. The bulk of the formation shows practically no bedding. It is composed primarily of quartz with a considerable amount of feldspar and scattered grains of epidote. Most of the sand grains show a fair degree of rounding, and many are frosted. The sandstone is fairly well sorted, but commonly contains well rounded granules of quartz or rock fragments 5 to 8 milimeters in diameter. In outcrop, the feldspars are kaolanized to a considerable extent, giving the rock a white color, and a somewhat greasy feeling when crushed between the fingers. One thin shaly lens is present near the bottom of the formation and crops out on a hillside just west of the Valv. (?) siltstone occurrence. It consists primarily of brown silty sandstones and shales with medium-to fine-grained sandy streaks. Some of the sandstones are calcareous and contain very scattered and poorly preserved impressions of mollusk shells. Three micro-paleontological samples were taken from these shales, but all proved to be barren.

As mentioned previously, several conglomeratic zones are present in the formation. These contain pebbles and small cobbles of quartz monzonite, quartz, and white rhyolite. The rhyolite is most abundant near the bottom of the formation. All pebbles and cobbles are very well rounded and show considerable wear, which is in marked contrast to the clasts in the overlying Chanac formation.

Although neither formation crops out in many places, an abundance of residual rock fragments in the surface mantle is helpful in distinguishing between the two. The well rounded fragments and complete lack of pink colored feldspar are the dominant characteristics of the Santa Margarita residual material

The Santa Margarita formation is Upper Miocene in age, Upper Mohnian or Lower Delmontion stage, and is in the <u>Bolivina marginata</u> foraminiferal zone of the San Joaquin Valley. According to G. C. Ferguson (43), it is equivalent to the upper Fruitvale shale, which occurs in the oil fields west of Bakersfield, California. Although all exposures in the area were examined carefully, no diagnostic fossil material was observed.

<u>Subsurface relations</u>

The general subsurface relationships of the Santa Margarita beds are fairly well known because most of the oil wells in this vicinity have penetrated at least the upper part of the formation. The newly discovered Slosson oil field, which is immediately northeast of the area mapped, produces from this interval. In outcrop, the Santa Margarita sandstones are overlain by a thick green claystone that contains a few thin sandstone members. This sharp lithologic break makes an excellent electric well log marker and can be easily recognized in the logs of all wells drilled in the immediate vicinity of the area mapped. However, to the west these characteristics are not as clear-cut. The Santa Margarita itself is characterized by relatively high second-curve resistivity values with a few extra high readings probably caused by calcareous streaks or conglomeratic zones. The base of the formation is generally well defined where it lies on the Pulv. shales, but local sandstones in the upper part of the Pulv. zone make electric well log correlations uncertain. Westward the proportion of sand in the Pulv. zone increases considerably.

The structural relationships of the Santa Margarita formation are portrayed in Plate III, which shows generalized contours on top of the formation, as well as isopachous lines. Only the faults that have positive surface expression are plotted on the map, however, it is recognized that many more minor faults are present also. The formation has a subsurface regional dip of 10° to 13° to the west-northwest, or toward the center of the valley.

Chanac Formation

The Chanac formation, named by J. P. Buwalda (16) from its occurrence near Chanac Creek, overlies the Santa Margarita sandstones with apparent conformity in the area mapped. It is exposed between the gravels of the Tunis fan and the alluvium of the San Joaquin Valley, and forms several low but distinct hills that owe their existence primarily to thick cappings of coarse terrace gravels. The homogeniety and flat structure of the Chanac beds form a topography very similar to that of the Santa Margarita formation, with a corresponding thick soil cover and scarcity of outcrops. However, trends of certain horizons, particularly conglomeratic or extremely clayey ones, give some indication of the attitude of the formation. Many of these trends are recognizable only when seen from a distance.

Due to the general lack of outcrops, well cores and electric well logs have been used for determination of lithologic characteristics in the Chanac formation. The Drilling and Production #15 well (7) penetrated approximately 900 feet of Chanac beds, however, thicker sections are present to the northwest. It consists of two distinct members, which, although not mappable, are recognized in all wells drilled within the immediate vicinity.

The lower member is dominantly green in color, but in outcrop several beds are tan. This member is about 100 feet thick in the area mapped. On top of the Santa Margarita sandstones is a massive claystone that ranges in thickness from 25 to 40 feet. It is remarkably pure, and often is referred to locally as a green plaster. Although the boundary between the Santa Margarita formation and this bed cannot be seen anywhere in the area, a marked soil change is present along the trace of the contact, and can be followed without difficulty. Overlying this claystone, which commonly is silty or gritty in its upper part, is a series of lenticular sandstones as much as 10 feet thick that are interbedded with gritty green clays. These sandy beds are characteristically gritty, coarse-grained, and arkosic. They contain abundant pink feldspar and an unusually high proportion of clay. Most of them are ill sorted, and their constituent sandgrains and rock fragments are very angular. In outcrop the lower sandstones of this member have a faint petroliferous odor.

The upper member is a monotonous series of silty and gritty mudstones broken only by conglomeratic, sandy, or pure claystone streaks. The conglomeratic zones contain pebbles and cobbles 3 to 5 inches in diameter, with scattered boulders a foot or more in diameter. The rock types represented include purple, pink, and white volcanic, granodioritic, granitic, quartz, gneiss, and schist. The fragments show only moderate wear, are ill sorted, and are contained in a matrix of gritty, brown clay. Carbonaceous material was observed in some samples, and several outcrops contained a faint petroliferous odor. Many sections appear to be permeable, but upon close examination usually contain a high proportion of clay or other fine-grained material. Beds of pure, brown claystone as much as 3 feet thick are also common throughout the section. The electric well log characteristics of this formation are identical to that of a thick series of shales, with low self-potential and resistivity readings. The only exception is the lower part of the section where the sandstones are more permeable.

Although the bulk of the Chanac formation is definitely Lower Pliocene in age, the exact relationships of its lower portion and the underlying Santa Margarita beds still remains an unsolved problem. According to Hoots (30), "the light gray Santa Margarita beds grade upward into the overlying buff strata through a transition zone 50 to 100 feet thick that is composed of beds of alternating gray and buff color". It was hoped that the present work would throw some light on this problem, but no such transition zone exists in the area mapped. The contact between the gray, marine Santa Margarita sandstones and the overlying continental Chanac beds is sharp, and so far as can be determined from subsurface observations, it is conformable in the vicinity of the area under study. Although sandstones are present above this contact, they are distinctly different from the underlying marine Santa Margarita beds. This situation also exists in subsurface parts of the formation.

One of the more recent studies connected with this problem is the investigation of Tertiary equidae in the Comanche Point area by A. B. Drescher (42). Well preserved remains of equidae were found beneath beds containing Santa Margarita invertebrate fossils. From a horizon of the transition zone, which Drescher included within the Chanac formation, a second vertebrate assemblage was found. This assemblage was Lower Pliocene in age and contained characteristics indicative of a hiatus between deposition of the two horizons, which are only 50 feet apart stratigraphically. Although no definite field evidence was obtained, the lithologic character of the sediments and the distinct gap between the two faunal assemblages led Drescher to believe that an important break in deposition exists between the Santa Margarita and the Chanac formations. Such a break is believed to occur at the base of the "transition zone", where it appears possible that a considerable thickness of coarse sediments was deposited and later removed by erosion without leaving a recognizable disconformity in the section.

The outstanding lithologic characteristic of the Chanac formation is its universally poor sorting, with angular rock fragments embedded in a matrix of clay and fine-grained clastic material. In all outcrops observed in this area, the formation shows little or no distinct bedding. The green clays at the base of the section, as well as much of the clay higher in the section, may be of bentonitic origin; however, no extensive ash or bentonite beds of this age are known to occur valleyward. A slight environmental change must have taken place after depositon of the lower member and before deposition of the upper member, as they are distinctly different in color, though otherwise nearly identical lithologically. This change presumably is due to the difference in the degree of oxidation of iron contained in the two units. The thick and widespread section of the Chanac formation, with its high proportion of clay and coarse angular clastic material, may indicate gentle uplift of an extensive, deeply weathered area of low relief. Although local tectonic activity can account for the bulk of the sedimentary characteristics found below the Chanac formation, it is felt that with the beginning of uppermost Miocene or lowermost Pliocene time a major widespread movement must have taken place. This movement, which began with the Chanac deposition, may have been the beginning of the most recent series of uplifts that gave the Sierra Nevada and Tehachapi Mountains their present relief.

Quaternary Deposits

Numerous and widespread terrace and alluvial deposits represent several periods in the more recent diastrophic and erosional history of the area. They range in age from possibly late Pleistocene to Recent. These deposits have been separated into the following groups on the basis of their relative ages: Pre-Tunis, Tunis, Post-Tunis, and Alluvium.

Lithologically these four members are very much alike, consisting as they do of coarse detrital material derived primarily from the adjoining crystalline rocks of the Tehachapi Mountains. The dominant rock types are fine-grained, hornblende schist, coarse-grained hornblende-plagioclase rock, medium-grained granodiorite, coarse-grained pyroxenite, pegmatitic material, and banded gneissic rock. These are arranged in the approximate order of decreasing abundance in the Pre-Tunis deposits, but granodiorite and banded gneiss become predominant in the more recent sediments, while the hornblende-plagioclase and pyroxenite rocks almost disappear. Included in these deposits are scattered fragments derived from the underlying sedimentary and volcanic rocks; most commonly represented are basaltic, rhyolitic, and quartzitic types. The size range of these materials is very great. Some of the boulders are as much as 8 or 9 feet in diameter, but 2 to 4 feet is much more common. These boulders are enclosed in a matrix of angular granitic material of smaller dimensions, which is oxidized in the older deposits to the deep redish brown typical of many exposed terrace accumulations.

These deposits range in thickness from a thin veneer of boulders to the alluvial deposits of the valley, which are at least 600 or 700 feet thick in the Tejon oil field. In contrast, the maximum thickness surrounding the area mapped is only about 200 to 300 feet. In drilling the Tunis Creek oil field 150 to 200 feet of boulders was encountered, and an exposed gully near the head of the Tunis fan contains more than 100 feet of these deposits. Valleyward those gravels overlie the Kern River series of Upper Pliocene and Pleistocene Age, which are composed of very similar material. In the Tejon oil field the combined thickness of these two formations averages 1,500 feet; they thicken somewhat toward the west and north. This extensive section of coarse fanglomerates and associated sediments attests to the rapidity and continuous nature of the uplift of the Tehachapi Mountains, which began in Middle or Late Pliocene time and evidently has continued to the present. The structural relationships of the various terrace deposits and their bearing on the recent history of the area will be discussed in the section on Geomorphology.

GEOLOGIC STRUCTURE

General statement

The area mapped is a small part of the foothill belt, which forms the southern edge of the San Joaquin Valley. The Sierra Nevada on the east consists of crystalline rocks and is characterized by a broad tilting to the west. The Tertiary rocks of the Coast Ranges are in marked contrast, and are strongly folded in a northwest-southeast direction. They are cut by numerous high-angle and thrust faults. These two great provinces are very different structurally, both in type and intensity of deformation, and as might be expected, the Tehachapi - San Emigdio Mountains and the adjoining foothills contain structures that are transitional between the two. The San Andreas fault, which transects the Coast Range Province, changes its strike in this vicinity from northwest-southeast to a more easterly direction, and bounds the San Emigdio Mountains on the south. In the vicinity of Lebec the San Andreas fault is joined by the Garlock fault, a major break that trends northeastward and bounds the Tehachapi Mountains on the southeast.

In the part of the Tejon Hills immediately north of the area mapped, Tertiary beds overlap the crystalline rocks and dip gently to the west. This region is intricately faulted and folded on a small scale, but in a broad way the structure is relatively simple. Southward the strike of the beds follows roughly the topographic outline of the valley and moderate northwest dips are encountered in the area mapped. Here folding is minor, and the chief structural features are cross faults and fractures parallel to the strike of the beds. The dips steepen in the vicinity of Pastoria Creek, where the formations swing to the west, and at Liveoak Creek the beds are overturned. Between here and Tecuya Creek relationships are masked by slumping and sliding, although steep dips, overturning, and cross faults are indicated by Hoots (30). As the San Andreas fault is approached, the region becomes one of intense deformation, and is characterized by such features as the Plieto thrust fault, the assymetrical Wheeler Ridge anticline, and the overturned folds between San Emigdio and Santiago Creeks.

Thus, from a regional standpoint, the structure of the area mapped is rather simple with deformation characterized by uplift and submergence. This type of deformation has given rise to numerous unconformities and overlaps, which have been complicated by faulting and minor warping.

Faulting

Two dominant sets of faults are present in the area mapped, one trending roughly parallel and the other perpendicular to the general strike of the beds. The strike set is developed only in the northern part of the area, and is represented by the Springs and Willow faults; whereas the dip set is represented by the Tunis fault to the south, as well as by a series of cross fractures associated with the Springs fault.

Tunis fault

The major fault that shows surface expression in the area is the Tunis fault which offsets the crystalline - sedimentary contact a horizontal distance of more than one mile. Although somewhat sinuous in detail, it trends N. 60° W. and dips 70° to 88° northeast. Its trace to the north is covered by Post-Tunis terrace deposits; however, from this point southeast for a distance of over two miles the fault can be mapped without difficulty. To the north it is marked by the juxtaposition of Temblor sediments with volcanic rocks. Southward the volcanic rocks are faulted against crystalline rocks with a thin slice of conglomeratic sediments between. The position of the fault in the crystalline rocks is marked by a low saddle developed in shattered material, and by springs in the next canyon to the east.

Hoots (30) shows a horizontal displacement for the fault on his structural map of this region; however field evidence noted by the writer indicates a vertical rather than horizontal displacement. This evidence is as follows:

1. The Tejon formation, which is estimated to be 100 feet thick on the west side of the fault, is absent from its east side. This formation is known to thin in a northeast direction and subsurface information indicates that it also thins to the southeast. Thus, if horizontal movement were entirely responsible for the displacement, Tejon beds should be present east of the fault.

2. The thickness of the volcanic rocks is vastly different on the two sides of the fault. This is not a positive indication of vertical movement, but suggests the possibility of minor vertical displacement on opposite sides of the fault, either by warping or fracturing during the extrusion of the upper part of the volcanic rocks.

3. Drag phenomena are very marked for about a half a mile on either side of the fault. It seems likely that to produce such characteristics along a strike slip fault, a considerable force vector in the lateral direction would be necessary. The resultant force vectors should be oriented approximately north-south, and flexures or secondary fractures with an east-west trend should be present either here or beneath the surface to the north. So far as could be determined in the present investigations, no such features exist.

The movement along the Tunis fault is considered to be essentially dip slip, with an average shift of approximately 3500 feet. Associated with the Tunis fault are large-scale drag effects that extend on both sides of the fault for distances of approximately half a mile. East of the fault, the drag takes the form of the fold shown in Plate XI . Here the volcanic rocks strike parallel to the fault and dip steeply northeast. Minor faulting also is present. To the west instead of folding, intricate branch faulting is present. The dip and direction of displacement of most of these branch faults are similar to those of the Tunis fault. The difference in drag effects on the two sides of the fault may be due to the abrupt thinning of the volcanic rocks as the fault is approached from the northeast.

The date of faulting can be fixed with a fair degree of certainty. The Temblor formation and all older rocks are displaced along the Tunis fault, whereas the Santa Margarita formation is relatively undisturbed beneath the surface to the north (Plate III). Owing to lack of foraminiferal data from wells drilled on either side of the extended trace of the Tunis fault, it is impossible to say with certainty just when the movement occurred in the interval between Temblor time and the end of Pulv. time. However, the main displacement was Pre-Santa Margarita, and occurred in either upper Middle Miocene or lower Upper Miocene time.

Springs fault

The most prominent structural feature in the northern part of the area is the Springs fault, which offsets the Tunis gravels and alluvium between the Tejon Hills and the Chanac - Tunis fan contact. It forms a prominent topographic scarp with a maximum measurable height of 25 feet. Springs along the fault trace form a distinct alignment of trees and thick vegetation. This alignment is very conspicuous on aerial photographs because of the sparse vegetation on the surrounding alluvial plain. In this area the Springs fault trends N. 40° E., with the upthrown block to the southeast. A shear zone was encountered at the bottom of Slosson #5 well (2). If this is indeed the Springs fault, its dip at this place would be approximately 65° to the northwest. Relationships in the Tunis Creek field indicate a somewhat steeper dip of the fault plane in the same direction. On the basis of data available at this time, it seems reasonable to conclude that the Springs fault is a normal fault with dips of 65° or more.

Associated with the Springs fault is a series of cross fractures that in at least two places offset the topographic scarp of the major fault. These show different relative displacements. They have no topographic expression except at the scarp, and may be of a strike-slip nature. Only the westernmost of these faults has been tenatively verified by drilling. The closure in the Tunis Creek field is believed to have been controlled primarily by the Springs fault and these cross faults. However, the lenticular nature of the Valv. sandstones in this vicinity also may be an important factor in the accumulation of oil. Closure in the Slosson field has been effected by the Springs fault and a northwest trending cross fault, resulting in accumulation of oil in the upper Santa Margarita sandstones.

The Springs fault is known to continue northeastward for some distance, where it, or a similar fault, and numerous cross faults control accumulation of oil in the many complex structures that are productive in the Tejon Hills. At the Slosson field, the topographic scarp is only 5 feet high. Subsurface data to the northeast indicate a scissors-type relationship, with a reversal in the direction of displacement, placing the upthrown block on the northwest side of the fault. The location of the fault southwest of the Tunis fan - Chanac contact is still largely an unsolved problem. A saddle separates Sulphur Hill and a knoll to the south. Although the knoll is topographically higher, according to the terrace gravel cappings it is structurally low. If the fault does continue through this saddle and the terrace gravels are correlative structurally, it reverses its displacement again. In the selection of the location for the Slosson's Reservoir Hill #1 well (4) by H. K. Armstrong, the Springs fault was extended across the southern face of the hill. This well was drilled to a depth of 1242 feet and bottomed in volcanic rocks without encountering any recognizable Pulv. or Valv. shale. Drilling and Production's #33 well (5), which is only 2100 feet north, penetrated a section of Pulv. and Valv. sediments about 660' thick. This indicates the possibility of a major dislocation of some kind between these two wells.

The Springs fault is known to have much greater displacements at depth than near the surface, and undoubtedly is an old shear zone in the crystalline rocks. The relationships of the Reservoir Hill #1 well (4) to the Drilling and Production #33 well (5) seem to indicate that this major break may continue between these two wells without any noticeable topographic expression. If so, one of the major movements along this fault took place between Pulv. and Santa Margarita time, with considerable uplift of the southeast block and removal of all Pulv., Valv., and perhaps some Temblor sediments by erosion. Plate III shows that displacement of the Santa Margarita - Chanac contact is probably small, if existent at all. The postulated relationships in this vicinity are shown on cross-section A - B, Plate II.

The most recent displacement along the Springs fault is believed to be limited to the area northeast of the Tunis fan - Chanac contact. There are no surface springs and no positive topographic expression of this fault southwest of this point, although the lack of springs can be easily explained by the absence of gravels to act as an aquifer. The tan member of the Chanac formation contains such a high percentage of clay that little water could be expected to travel through it, especially in a vertical direction or up a steep fault plane.

Willows fault

About one mile southeast of the reservoir along Willow Creek is a group of trees that line the stream for a distance of 1000 feet. They stand out conspicuously in the bare valley. On the downstream side of the trees is a wide zone of slumped and very boggy ground. North of the trees the creek has cut a trench 10 or 12 feet deep, and the basal green claystones and overlying sandstones of the Chanac formation are exposed in its bottom. The projected contact between the Chanac and the Santa Margarita formations crosses the creek southeast of the end of the trees. These structural and stratigraphic relationships suggest a displacement at the boggy area of approximately

125 feet, with the upthrown block to the northwest. This is opposite in direction to the known displacement along the Springs fault. The localization of moisture in this area might be explained by the notch in the Chanac - Santa Margarita contact plane acting as a spill point for the Santa Margarita aquifer; however the trees are located downstream rather than upstream from the postulated spill point, which is not the usual case.

A gully cutting through some 40 feet of Tunis fan gravels exposes Santa Margarita beds, which end abruptly to the southeast and are replaced by green Chanac claystones. If this is another fault relationship, it involves the same relative amount and direction of displacement as the fault present in Willow Creek. At the east end of South Hill another anomalous structural relation was found. The Chanac beds abruptly change strike, and to the east they dip more steeply than normal for this area, thus indicating the possibility of faulting. The displacements at the east end of South Hill, along Willow Creek, and northeast on the Tunis fan show very good alignment, and probably are located along a single line of shear. This line of deformation has been designated the Willows fault. No evidence is available as to the dip of this probable fault plan, which if present may be offset by several cross faults similar to those associated with the Springs fault. Although the maximum observed offset of the Willows fault is only 125 feet it is believed to be similar to the Springs fault with a much larger displacement below the Santa Margarita sandstones. If it has this relationship, and if the silty sandstones observed at the base of the Santa Margarita formation in outcrop are equivalent to the Valv. zone, then a wedge of Valv. and possibly Pulv. sediments may be preserved south of the Willows fault. The postulated relationships in this vicinity are shown on cross-section A - B, Plate II.

Many minor water seeps and springs are present in the part of the area nearer to the crystalline rocks. Many undoubtedly are related to faulting or fracturing; however, no positive evidence of extensive faulting relating to them could be found. Many alignments are observable on aerial photographs, especially to the north, that may or may not have any structural significance. All those features which from a structural standpoint are highly speculative have been purposely omitted from the geologic map,(Plate I).

Folding

Folding in the area is a very minor feature, and consists primarily of drag phenomena along faults. The drag folds associated with the Tunis fault already have been discussed; similar features undoubtedly are present in connection with the Willows and Springs faults to the north. Thirty degree dips in the Valv. zone were found in Tunis Creek field, where a dip of 10° to 15° normally would be expected. This slight steepening may be due to drag effects along the Springs fault and related faults.

There is a gradual increase in dip as the crystalline rocks are approached. A maximum dip of 75° was observed in the Tejon rocks immediately east of Pastoria Creek, and upward in the section this decreases to 55°. The attitude of the central portion of the overlying Tecuya formation is about 35°, and still farther north the volcanic rocks show a dip of 28°. These same general relationships hold northeast of Pastoria Creek, where the attitude of the basal beds decreases to about 35° near the Tunis fan.

There is a suggestion of anticlinal folding in South Hill, where the strike of the Chanac beds changes from N. 30° E. to approximately east-west. This change, however, could be due to recent faulting. Whether the structure exhibited in South Hill is due to folding or faulting, some closure is likely to be present against the Willows fault.

Structural countours drawn on the top of the Santa Margarita formation show two distinct fold axes, a plunging anticlinal nose where the strike of the beds swings from northeast-southwest toward the south, and a corresponding synclinal axis where the contours presumably swing westward to follow the topographic and structural outline of the valley. Although the folding appears quite simple on top of the Santa Margarita formation, it probably is only a reflection of more intense deformation below. A considerable amount of drilling has been done along this plunging anticlinal trend. Most wells reported shows of oil and the Reserve 2 - 1 well (2) even produced for a short period of time. The last attempt to locate production along this trend was made in February, 1950. However, no important shows of oil or gas were encountered and the well was abandoned.

Unconformities

The occurrence of several unconformities in the section of this area is thought to be due primarily to proximity of the edge of the basin of Tertiary deposition. The adjacent regions were strongly positive and active areas throughout much of Tertiary time, as evidenced by the lithology of the Miocene and younger sediments and the unconformable over-lap relationships throughout the entire section. Due to the importance of these structures each will be described briefly.

The contact between the crystalline rocks and the overlying sediments from Pastoria to Tunis Creek is depositional throughout its length. Many excellent exposures are present, and in no place was shearing of any kind observed. There also is a notable lack of intense fracturing in the adjoining sedimentary rocks, even to the west where the contact dips as steeply as 75°. In most places the contact is overlain by a thin basal conglomerate that contains coarse, angular fragments derived from the adjacent crystalline rocks. In some places well sorted sands were observed to wrap around irregularities of the old land surface. The best example of this is just east of the Tunis fault, where a quartzite bed forms a resistant ridge. Here, as in many other places, the detailed outline of the contact is very sinuous. Where the mountain front dips almost as steeply as the contact, isolated residual boulders from the sediments can still be found high on the slopes.

The Tejon sediments are known to thicken to the southwest, west, and northwest. In the vicinity of the mapped area the bulk of this thickening takes place along the basal contact; however, higher members also are present to the west. This indicates that the marine Tejon beds accumulated in a trough that trended roughly to the north. This is substantiated by the fact that the limit of marine Eocene deposition to the north is somewhere in the vicinity of Bakersfield, thus giving a generalized zero isopach line for these sediments a slightly west of north trend.

Unconformably overlapping the Tejon formation are the Tecuya beds, which bear the same general relationship to the Eocene sediments as they themselves do to the crystalline rocks. The Tecuya formation thickens locally to the southwest and appreciably to the north. The greatest thickening is in a northwest direction, and although the structural relationships are not known between outcrop and the Richfield Tejon Ranch #1 well (1), the addition of most of this section is thought to occur at its base. The general isopachous lines for this formation trend in a direction slightly east of north in the area mapped, swinging northward or to the northwest, as the Tejon Hills are approached. The deformation prior to and active during the deposition of this formation marks the establishment of forces that eventually were to block out the general configuration of the southeastern part of the San Joaquin Valley.

Overlying the Tecuya formation with a mild disconformity is the thick section of volcanic rocks of Lower - Middle (?) Miocene age. Although no great angular discordance was observed in outcrop between these basalts and the underlying sediments, the marked thickening of the Tecuya formation to the northwest suggests that there may be a slight angular relationship between the two units. The volcanic rocks probably have the same general structural relationships as the Tecuya formation. The zero isopach of the volcanic rocks is known from wells drilled in the eastern part of the area; however, its true relationships are masked in this vicinity by the interfingering of sedimentary deposits. The extreme thickness of volcanic rocks east of the Tunis fault may be explained by either gradual downwarping or minor faulting along the line of the Tunis fault during the upper part of the volcanic period, or the local accumulation of an extra thick series of flows, which to the west were flanked by sediments being deposited at a rate comparable to building up of the volcanic pile. Field evidence indicates that both of these geologic processes may have been active.

West of the Tunis fault the volcanic rocks are overlain by the Temblor formation with a very marked erosional unconformity. An angular discordance of 10° to 15° between these two units also is observable in this locality. A wedging out of the Temblor formation against the volcanic rocks is suggested northeast of the Tunis fault; however, it is in this vicinity that the volcanic section thickens abruptly, primarily by addition of material to the upper portion of the mass. Relationships are masked to the southwest by terrace and alluvial deposits, but between Pastoria Creek and the Liveoak fault the distribution of the volcanic rocks is rather limited and disconnected. From relationships observed in the area mapped, this is thought to be due in part to removal by erosion of much or all of the underlying basalt. Where removal was complete, the Temblor sediments lie directly on Tecuya beds, from which they are almost indistinguishable lithologically. As was stated previously, relationships of the Temblor formation to the north are very uncertain, owing to the inconsistency in the determination of its top.

Lying with distinct angular unconformity on top of the Temblor formation are the Santa Margarita formation and the thin outcrop of Valv. (?) siltstones. These formations truncate completely the Temblor formation and a considerable thickness of volcanic rocks, and are themselves in part covered by the Tunis gravels. If the thin belt of siltstones west of the Tunis fan is equivalent to the Valv. zone, the major deformation blocking out the present outline of this part of the valley took place during Middle Miocene time, or between the deposition of the Temblor formation and the overlying Valv. zone. This period is one of the likely times for the major Tunis fault movement. If these siltstones contain a reworked Valv. faunal assemblage and are Santa Margarita in age, the major movement could have come at the end of Pulv. time. If they are related to the

Temblor formation, which also is reported to contain Valv. fauna, the deformation would be set back within the Temblor depositional period. In either case, the seas in which the Santa Margarita formation and possibly both Pulv. and Valv. zones were deposited never extended much farther south or east than the limits of the present mapped area.

A widespread but minor unconformity is present between the Valv. and Pulv. zones. In the Tejon oil field vertical or steep dipping beds have been reported in the Valv. zone that were overlain by relatively flat dipping Pulv. siltstones. A slight angular relationship within the area mapped is suggested from scattered paleontological information and electric log studies. This relationship is best shown on cross-section A - B, Plate II.

The contact between the Pulv. zone and the Santa Margarita formation represents another major period of deformation and erosion. The present production in the Tejon oil field from the Rose Bright zone is coming from Valv. sandstones containing both folds and faults that are not present above the base of the Santa Margarita formation. The Santa Margarita formation characteristically lies on older and older beds as it approaches the edge of the valley in a southeast or east direction. Along the Springs fault, it overlaps Pulv. sediments in the vicinity of the Tunis Creek oil field, as well as the entire Valv. zone between this point and the Slosson oil field. To the south the Santa Margarita formation truncates the Pulv. zone, Valv. zone, Temblor formation, at least part of the volcanic rocks, and may even lie on

Tecuya beds east of the Tunis fan. In the Tejon Hills just north of the Tejon Ranch Headquarters it overlaps crystalline rocks. From all indications, the edge of the basin in which the Santa Margarita formation was deposited conformed rather closely to the present general configuration of this part of the valley. According to L. W. Richards (verbal communication) Santa Margarita beds are present along the Garlock fault; he feels that an embayment heading back through the Pastoria Creek region extended the Santa Margarita sea some distance to the south. No detailed study of this aspect of the problem was made.

The nature of the Santa Margarita - Chanac boundary has been discussed on earlier pages. These units apparently are conformable in the area mapped; however, in the Tejon Hills and toward the valley the relationship is far from being solved. The contact between the Chanac formation and the overlying Kern River series is almost certainly unconformable near the edge of the basin, and the Kern River series itself is undoubtedly overlain unconformably by the alluvial deposits of the valley. Thus, in this part of the valley the unconformity is an important geologic structure, both from a historical standpoint and also in problems pertaining to the accumulation of oil and gas.

One of the most interesting unsolved problems in this area is the nature of the deformation in the crystalline rocks. The absolute lack of shear along the contact with the overlying sedimentary rocks, even where dips are as high as 75°, is indicative of considerable folding in the crystalline rocks themselves. Relationships within the granitic core of the Tehachapi Mountains and between it and the metamorphic rocks also are problems that to date have been largely neglected. The metamorphic and granitic rocks in this region are of such character as to facilitate a detailed structural study, being in large part moderately to highly foliated. Aerial photographs as well as good topographic maps of the area are available. The relief, although high, is advantageous in that good outcrops are abundant. Moreover, underbrush is almost nonexistant.

GEOMORPHOLOGY

The most outstanding topographic feature in this part of the valley is the bold scarp of the Tehachapi Mountains, which rise abruptly from the foothills and valley floor to a height of 3000 feet in a horizontal distance of about three miles. Complex fault relationships exist along much of the length of this mountain front to the west; however, in the area mapped the contact between the crystalline rocks and the overlying sedimentary rocks is depositional and exhibits no evidence of tectonic movement. In several places to the east the slope of the mountain front is the same as the dip of the crystalline - sedimentary contact. Isolated sedimentary material high on the slope above this contact demonstrates the youthful characteristics of the lower part of the scarp. This relationship probably becomes more pronounced eastward where the dip of the crystalline - sedimentary contact is reported to be 10° to 15°. These relationships suggest that at least in this vicinity the core of the Tehachapi Mountains has been uplifted primarily by means of folding, rather than faulting. As pointed out by Hoots (30), the major drainage in the crystalline rocks shows a marked northwest trend; this he attributed to possible shear zones without appreciable Tertiary displacement. This northwest trend is not only true for the major drainage, but also for most of the minor tributaries. However, the distinct northwest - southeast grain may be due to foliation of the metamorphic rocks rather than to the shearing suggested by Hoots (30).

One of the most notable topographic anomalies in the area mapped is a series of low hills to the north referred to locally as the Chanac Hills. They rise 50 to 200 feet above the general level of the adjacent alluvium, and the most conspicuous among them are South Hill, Reservoir Hill, and Sulphur Hill. The remarkable preservation of the Springs fault scarp, which attests the recency of its displacement, poses the question - How much of the present relief of these anomalous hills is due to erosion and how much, if any, is due to recent tectonic movement? Almost every hill is capped with variable thicknesses of bouldery terrace gravels. On the basis of the contour map on top of the Santa Margarita formation (Plate III), and the areal and vertical relationships of the Pre-Tunis terrace deposits it is believed that these bouldery cappings have been the primary cause for preservation of these hills. Relatively flat surfaces on top of Reservoir Hill and South Hill slope at lower angles than younger Pre-Tunis surfaces. This relationship could be due to recent deformation of these oldest deposits. However, if these terraces were cut by Pastoria Creek drainage, the low slopes would not be abnormal. Since good outcrops of the Chanac formation are almost nonexistent in most of the area, precise determination of the attitudes and elevations of the cut surfaces of these terrace remnants might be of great help in determination of the recent structural history in this vicinity.

South Hill is one of those that is indicative of possible recent deformation. It is capped by terrace gravels and contains three extensive surfaces. Two, which appear to be structurally related, are separated by a third which is approximately 45 feet higher. Contacts between these surfaces are distinct topographic scarps. The highest surface is arched, but not so strongly as the underlying Chanac formation, and if the two lower surfaces are correlative and unfaulted, they also show a very slight arching along the same axis. One interpretation of the structural history would be - Chanac folding, truncation and deposition of the upper gravels, continued folding along the same axis, partial dissection of the upper surface with deposition of the lower gravels, and finally, slight warping of the lower surface. An alternative hypothesis would involve - beveling of deformed Chanac beds, followed by deposition of a thick series of gravels, and breaking up of the original terrace surface by faulting and folding. Owing to the complete lack of Chanac outcrops, either interpretation is equally valid on the basis of available data. Only a great deal of excavation with a bulldozer could completely clarify the structural relationships in this locality.

The above description of South Hill gives some idea of the variety of conclusions that could be reached concerning the structure and recent development of this part of the area. Numerous wells have been drilled in and adjacent to this region, thus far without any success, and undoubtedly several more attempts will be made, based on new or varied interpretations of this seemingly complex area. The map in

Plate III, which is contoured without any faults, shows that the structure of the Chanac and Santa Margarita formations in this area conceivably could be rather simple. However, some faulting similar to that known to the northeast probably is present in this area.

Immediately north of Reservoir Hill is a slightly elevated surface about half a square mile in area. It is bounded on the west by a scarp formed by the Pastoria Creek drainage, and on the north by a similar scarp formed by the Tunis Creek drainage. On aerial photographs this surface is marked by a random distribution of light colored circular areas on a dark background. The topography of this surface, which on the whole is very flat, consists of numerous humps and hollows with a relief of only a foot or two. It is a surface seemingly incapable of formation by normal erosional processes, containing many small closed depressions and little or no drainage development.

It has been suggested this might be the remains of a gigantic mud flow or low angle slide, with material being derived from an area to the south. The Chanac formation contains a very high proportion of clay, and if saturated, conceivably could move on a very low angle surface if support were removed. This could form an extensive surface with a topography similar to that present. However, the mechanics of movement and also the saturation of such an impervious mass is somewhat in question. The excellent preservation of the features on this surface indicates that if slumping is responsible for this topography, movement has been very recent. If movement has been this recent, slump scars should be preserved to the south, and the irregularities of this anomalous surface should show a roughly concave pattern. No such features exist. A large surface underlain by thick terrace deposits is present on top of Reservoir Hill identical in topography to this lower anomalous surface. Examination of the electric logs of the Drilling and Production #15 well ( ) and the Thermo #1 well ( ), which were drilled from points on the surface to the north, shows a zone, approximately 200 feet thick, characterized by very high self-potential and resistivity readings. The base of this zone is very sharp, and beneath it are the typical uniformally low self-potential and resistivity readings of the Chanac beds. This point marks the base of the boulder beds that make up the terrace and alluvial deposits in this vicinity. On the basis of the above information this anomalous topography could hardly have been formed by recent slumping. The mechanism responsible for its formation may be due to a form of differential compaction aided by downward movement of the finest particals by percolating ground water.

The area southwest of Reservoir Hill also is marked by peculiar drainage characteristics, with slightly ponded areas. This could be explained by slumping from South Hill and Reservoir Hill, or by recent deformation. However, south of South Hill similar features can be found, that have been formed by normal erosional and depositional processes.

It is thought that the seemingly anomalous features in the vicinity of Reservoir Hill can be adequately explained by the action of Pastoria Creek drainage which first, by cutting below its present surface, established tributary profiles. It then began to aggrade, and being more active than the tributary streams, had a slight tendency to dam them.

The more recent diastrophic and erosional history is recorded by the numerous terrace and alluvial deposits of the area. These have been classified according to their relative ages into four main groups as follows: Pre-Tunis, Tunis, Post-Tunis, and Alluvium. The oldest deposits consist of a series of isolated gravel masses that cap the more prominent hills in the northern part of the area. These gravels were deposited on surfaces cut prior to the development of the Tunis fan. Although many of these terraces appear related, no positive conclusions can be drawn without more detailed information on their attitudes and elevations. It is fairly certain, however, that at least three erosional and depositional periods are represented. Reservoir Hill, as well as South Hill, appear to be somewhat deformed, and show particularly flat gradients. The relationships on Reservoir Hill and South Hill conceivably could be caused by the action of Pastoria Creek drainage, although all other Pre-Tunis terraces in this vicinity undoubtedly are the result of Tunis Creek activity. There are three isolated high-level terraces to the south, one east of the fan and two to the west. The terrace, which is less than half a mile west of the point where Tunis Creek emerges from the mountain front, stands 160 feet above the level of the Tunis fan. This indicates that at least during the deposition of the Pre-Tunis gravels the mountain front had approximately the same relationship to the Tertiary foothills as it does today.

Tunis Creek emerges from the crystalline rocks in a narrow, steep-walled canyon that empties onto a long, extensive, aggraded surface that slopes gently to the north at an angle of about 3°. Gravels at least 150 feet thick have been observed in an old channel near the head of this fan. The present stream has been entrenched in these alluvial deposits during three or four periods of rejuvenation, and where it leaves the crystalline rocks now stands approximately 75 feet below the present level of the fan. To the west minor tributary drainages, which stand 150 to 200 feet below the present Tunis surface, have carved the prominent scarp along the western edge of the fan shown in Plate XVIII. Along this scarp the thickness of the alluvial gravels ranges from 15 to about 40 feet.

Between South Hill and the outcrops of Temblor and volcanic rocks is an extensive surface that has been designated as Post-Tunis. This surface slopes gently northwestward toward the alluvial plain, and is separated from it by an irregular topographic scarp with a maximum height of 45 feet. Although the general outline of this scarp has been controlled primarily by Pastoria Creek drainage, numerous irregular indentations have been formed by head-has been one of repeated periods of rejuvenation in which extensive surfaces have been cut, separated by relatively stable periods in which aggradation took place. This has been true at least since the development of the Tunis fan, and it seems reasonable to assume that the Pre-Tunis deposits, which represent several stages, were formed by similar processes.

The Tunis, Post-Tunis, and Alluvial surfaces are aggraded surfaces, or very nearly so, and yet they have quite different slopes. The grade of the Tunis fan is more than twice that of the Alluvium to the west, and that of the Post-Tunis surface is intermediate between these two. If the Pre-Tunis terraces near the head of the fan correlate with one of the lower levels to the north, these also show the same relationship. This conceivably could be caused by cyclic changes in climate, with each period of aggredation becoming more moist than the preceeding one. If this were the case, the formation of these various surfaces might be correlated with the known glacial and inter-glacial periods of the Sierra Nevada. This would date the oldest terraces as early Pleistocene in age. This concept, although simple and complete, will not stand in the light of present knowedge of recent geologic history of the Southwest. It seems highly unlikely that minor topographic features like the Chanac Hills should be preserved if all direct evidence of major early Pleistocene drainage in the Mojave Desert region has been erased (R.R. Miller, 46). Also, the almost perfect preservation of even the Tunis fan seems more indicative of increasing aridity rather than an increase in moisture. This would make these surfaces very young geologically, placing them in the time interval between the last ice age and the present. The youthful relationships along the bold scarp of the Tehachapi Mountains also lends credence to this deduction. If this is the case, then only the oldest terraces, the ones capping Reservoir Hill and perhaps South Hill , could possibly be crowded into the uppermost Pleistocene.

If cyclic changes in climate can be ruled out as the dominant factor in the formation of these surfaces, the only other alternative is rejuvenation of the streams by tilting. In view of the known recent tectonic activity in the area, this seems to be a logical conclusion. Thus, the recent history in this part of the valley can be visualized as a repeated series of events which in each case began with uplift of the core of the Tehachapi Mountains. This uplift caused minor tilting of the foothill region, increasing the gradients of all streams, allowing them first to cut down, and eventually, as uplift ceased, to cut laterally and aggrade their cut surfaces. The next period, as the former, would be initiated by a new uplift of the mountains to the southeast. The same processes would be repeated, possibly leaving behind terraces as evidence of the former period. These terraces if extensive enough would show slightly steeper grades than the newly formed surface. It is thought that by a repetition of such events the Tunis, Post-Tunis, and Alluvium surfaces were formed. Most of the Pre-

Tunis terraces probably were developed in a similar manner. The Pre-Tunis gravels to the north indicate a gradual southward recession of a hypothetical base-level as the San Joaquin depression became filled with alluvial debris. During this entire period the mountain front consisted of crystalline rocks and stood in the same relative position that it does today.

This investigation, as most others similar to it, brings up the problem of dating these various deposits. Hoots (30) dated all the more recent deposits that show deformation as Pleistocene. Most workers arbitrarily date all terrace accumulations as Pleistocene, and designate only alluvial material as Recent. It is generally agreed that the boundary between the Pleistocene and Recent lies at the end of the last glacial stage. The arbitrary and indefinite nature of this division is a sore spot in all geomorphic investigations, which often indicate that the Recent epoch may be only the latest inter-glacial stage. Therefore there may not be any great distinction between the Pleistocene and Recent, for so far as is known both are merely parts of the Quaternary epoch, in which glaciation has played an important role.

GEOLOGIC HISTORY

Very little is known concerning the Pre-Tertiary history of this part of the San Joaquin Valley due to the complete lack of unmetamorphosed sedimentary deposits of this age in this vicinity. This area probably underwent activity similar to that in the Sierra Nevada region to the north, with Mesezoic intrusion, followed by widespread uplift and erosion. In many places the granitic core of the Tehachapi Mountains was uncovered by Eocene time; however, in the area mapped the crystalline rocks consist primarily of metamorphic gneisses and schists.

In Middle Eocene time general subsidence led to widespread marine conditions in this region that brought about a transgression of the sea from west to east. The sea covered this entire area, and the shallow water sediments of the Tejon formation were deposited. Although marine Oligocene and Lower Miocene beds are present in the vicinity of San Emigdio Creek, uppermost Eocene, Oligocene, and possibly Lower Miocene sediments are absent along the southeast edge of the valley. Thus a period of extensive uplift took place before deposition of the Tecuya formation in the mapped area. The Tejon sediments were tilted westward and the upper part of the formation was removed by erosion.

This period of uplift and erosion was followed in Lower or Middle Miocene time by a period of subsidence, in which the alternating marine and fluviatile sediments of the Tecuya formation were deposited. The lithologic character of the sediments, as well as their structural trends, indicate that strong positive forces were active south and east of the present area. Extensive areas of quartzitic rocks were uncovered at this time. The eastern part of the mapped area apparently was slightly negative, as marine conditions prevailed here during much of Tecuya time. It is believed that the tectonic activity immediately prior to, and during this period, was the first to establish the broad structural outlines of the southeast part of the San Joaquin Valley.

Toward the end of Tecuya time widespread volcanism of the fissure type was initiated in this general region. Subsidence continued, and a thick series of basalt and andesite flows with associated pyroclastics accumulated over the entire area. Minor sills and dikes of basaltic composition also were intruded at this time. Strong negative characteristics again were exhibited in the eastern part of the mapped area where an unusually thick accumulation of volcanic flows are intercalated with conglomeratic marine sediments. This volcanic period was terminated by a series of rhyolitic extrusions to the south or east.

Tectonic activity in the region adjacent to the mapped area was fairly intense in Middle Miocene time. This is shown by the marked unconformity at the base of the Temblor formation and by the lithology of the overlying sediments. This activity culminated in movements which established the major structural trends in this area, and may have caused movement along the Tunis fault. This period was followed by one of relatively quiet subsidence in which the uniformly fine grained Valv. and Pulv. sediments were deposited. Irregularities in this subsidence caused minor oscillations of shore lines that led to deposition of lenticular sandstones. Although no major stratigraphic break can be demonstrated between the Valv. and Pulv. zones in the immediate area, a distinct faunal change occurs at this horizon. Evidence of local deformation in the vicinity of Tejon field also has been reported. This relatively stable period was terminated in Upper Miocene time by the post-Pulv. orogeny, which raised the core of the Tehachapi Mountains and more definitely blocked out the present structural outlines of this part of the San Joaquin Valley. Considerable folding and faulting took place at this time, and widespread erosion beveled progressively older rocks toward the edges of the basin.

Subsidence brought about another transgression of the sea into this part of the Tejon embayment, and the coarse-grained, near-shore deposits of the Santa Margarita formation were deposited. The bulk of the sediments in this formation probably consist of reworked detrital material derived from uplifted areas to the south and east. At the end of Santa Margarita time flood plain conditions prevailed in this part of the San Joaquin Valley. The clay and fine clastics, which make up the bulk of the Lower Pliocene Chanac formation, may have been derived from a gently uplifted area of low relief to the east. The coarse arkosic fraction of this formation undoubtedly was derived from local uplifted areas.

By Middle Pliocene time the intensity of tectonic activity in this region increased and valleyward subsidence led to deposition of the coarse grained Kern River series. Continued uplift in Pleistocene time resulted in the present elevation of the Sierra Nevada and Tehachapi Mountains. This uplift was accompanied by general subsidence of the San Joaquin depression and accumulation of thick alluvial deposits. The numerous high level terrace deposits and the well preserved Springs fault scarp indicate that tectonic forces probably are still active in this area.

APPENDIX

Wells Drilled for Oil Referred to in This Report

Number	Name of Well	Location (S.B.B.M.)
(1)	Richfield Tejon Ranch #1	Sec. 2, T.10N., R.19W.
(2)	Reserve 2 - 1	Sec. 2, T.10N., R.19W.
(3)	Ohio B - 1	Sec. 36, T.11N., R.19W.
(4)	Slosson Reservoir Hill #1	Sec. 32, T.11N., R.18W.
(5)	Drilling and Production #33	Sec. 32, T.11N., R.18W.
(6)	Thermo #1	Sec. 29, T.11N., R.18W.
(7)	Drilling and Production #15	Sec. 29, T.11N., R.18W.
(8)	Drilling and Production #45	Sec. 19, T.11N., R.18W.
(9)	Richfield Tejon Ranch #2	Sec. 19, T.11N., R.18W.
(10)	Western Gulf Tejon Ranch #1	Sec. 29, T.11N., R.18W.
(11)	Richfield B - 1	Sec. 28, T.11N., R.18W.
(12)	Slosson #5	Sec. 22, T.11N., R.18W.

APPENDIX

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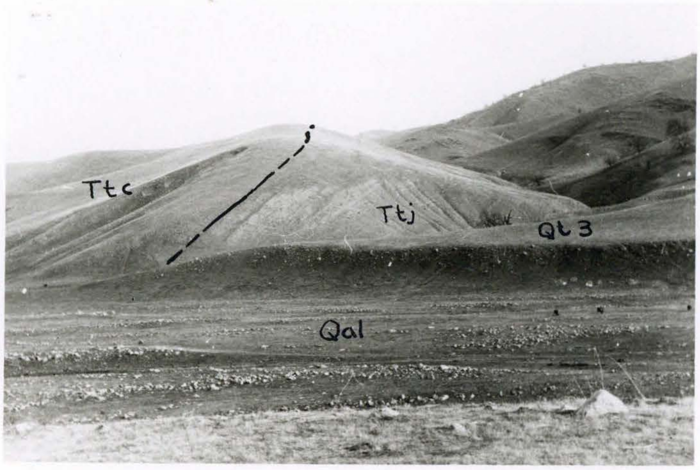

PLATE VI

View looking eastward across Pastoria Creek
Calcareous reefs give a bedded appearance
to the Tejon formation.

PLATE VII

Feeder dike cutting Tecuya beds and volcanic rocks.

PLATE VIII

Outcrop of dacitic agglomerate

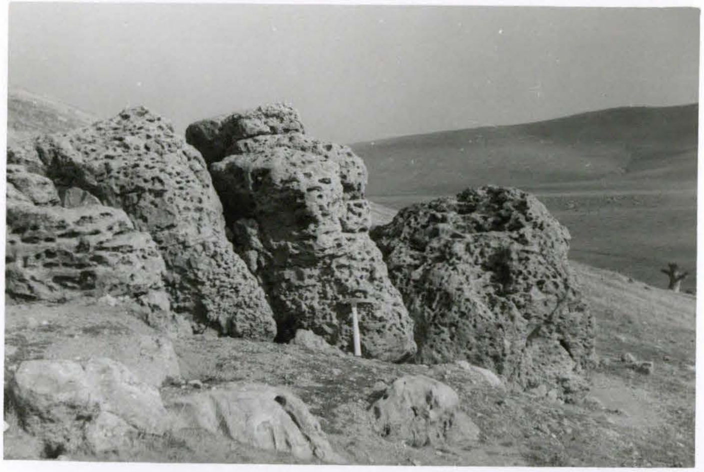

PLATE IX

Fretted surface on outcrop of calcareous Temblor sandstone

PLATE X

Large rhyolite boulder in upper member of Temblor formation
Gentle rolling topography of Santa Margarita formation can be seen in background.

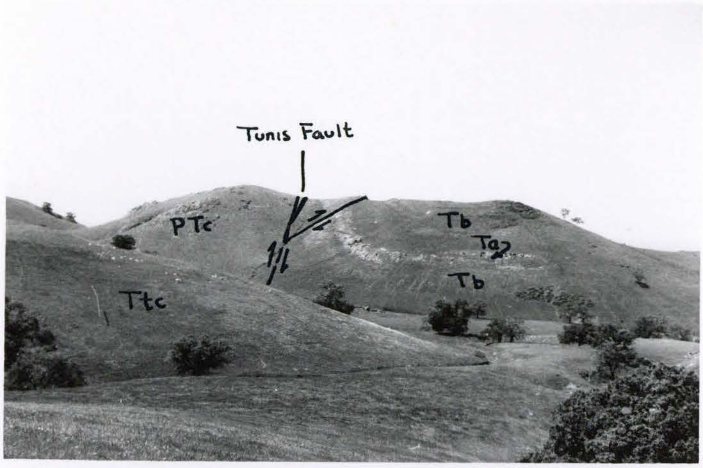

PLATE XI

Looking northwestward at Tunis fault.
Drag effects shown by agglomerate bed.
A thin slice of conglomerate separates the volcanic rocks from the crystalline rocks in the saddle.

PLATE XII

Looking southwestward at trace of Tunis fault.
Sill crops out on crest of hill to left.

PLATE XIII

Postulated trace of the Willows Fault in Willow Creek valley.
Three terrace levels can be seen on South Hill to the west.

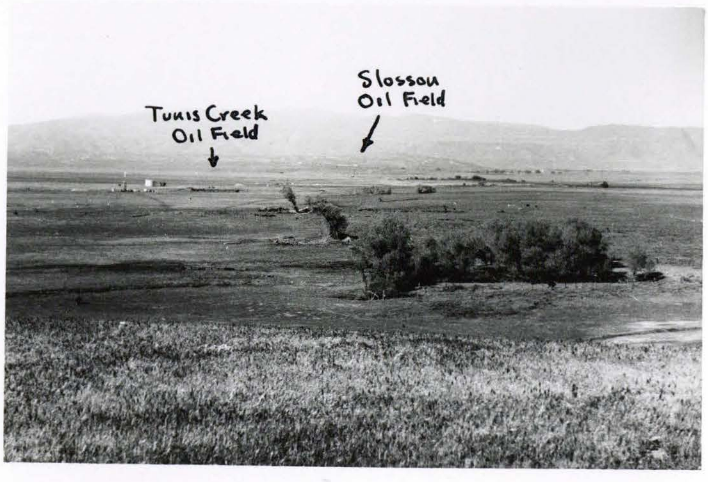

PLATE XIV

View taken from Sulphur Hill looking north-eastward along the Springs fault scarp.

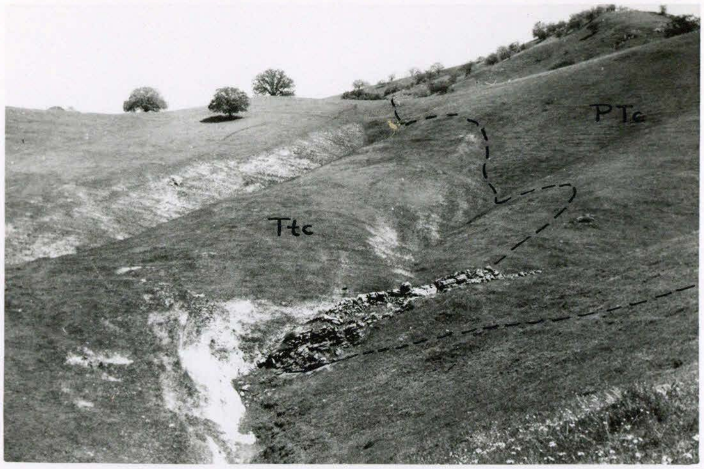

PLATE XV

Depositional contact between the Tecuya beds and crystalline rocks.
Resistant quartzite bed is present in foreground.

PLATE XVI

Anomalous Pre-Tunis surface north of Reservoir Hill.

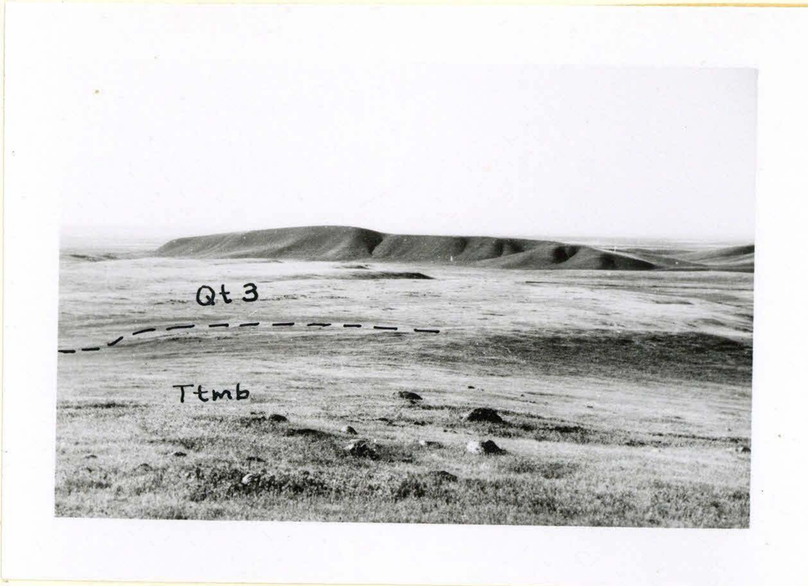

PLATE XVII

Looking northward at South Hill across extensive Post-Tunis surface

PLATE XVIII

View taken from Pre-Tunis terrace remnant near crystalline rocks.
West scarp of Tunis fan is shown in foreground.
The gentle rolling topography of the Santa Margarita and Chanac formations can be seen to the north.