STRUCTURE AND OIL RESOURCES OF THE SIMI VALLEY, SOUTHERN CALIFORNIA.

By William S. W. Kew.

INTRODUCTION.

Within the last few years considerable activity has been manifested in the development of a small oil field about 2½ miles north of Santa Susana, Cal., a small town on the Coast Line of the Southern Pacific Co., about 32 miles northwest of Los Angeles, in the Simi Valley, Ventura County. (See index map, fig. 45.) The first wells in this region were put down by the Simi Oil Co. in 1900 near an oil seepage 1½ miles east of the present producing fields. They obtained some oil of rather high gravity (32° Baumé) but not enough to make it a paying investment. In 1912, after a geologic report had been made, drilling was begun by the Petrol Oil Co. on the axis of an anticline in Tapo Canyon, where a well was brought in which yielded a fair production of light oil (35°–36° Baumé). Since then a number of wells have been drilled with success.

Although this region has been visited frequently by geologists, comparatively little information has been published[1] concerning the geology either of the oil fields or of any other area on the south side of the Santa Susana Mountains. In the fall of 1917 a geologic survey covering the whole Simi district was made by the writer in order to determine as far as possible from surface indications, aided by drilling records, the future possibilities of the existing fields and to find any other localities where the structure is favorable for holding oil. This paper is preliminary to a complete report on the geology and oil resources of the Santa Clara Valley, Santa Susana Mountains, and Simi oil districts, which is now in preparation. During this work the writer was assisted by Carroll M. Wagner, whose notes have aided materially in making this report. Opportunity is taken to express the writer's appreciation for the uniform kindness and much valuable information given by the operating oil companies and by the residents of this district.

[1] Johnson, H. R., Geologic notes on Santa Susana district: Western Eng., vol. 2, No. 5, pp. 383-386, 1913. Waring, C. A., Structural geology south of the Santa Susana district: Western Eng., vol. 3, p. 470, 1913. Waring, C. A., Stratigraphic and faunal relations of the Martinez to the Chico and Tejon of southern California: California Acad. Sci. Proc., vol. 7, No. 4, pp. 41-124, pls. 7-16, 1917.

SURFACE FEATURES.

The area shown on the map (Pl. XLI) lies between the Santa Susana Mountains and Oak Ridge on the north and the Simi Hills on the south. The Santa Susana Mountains and Oak Ridge extend

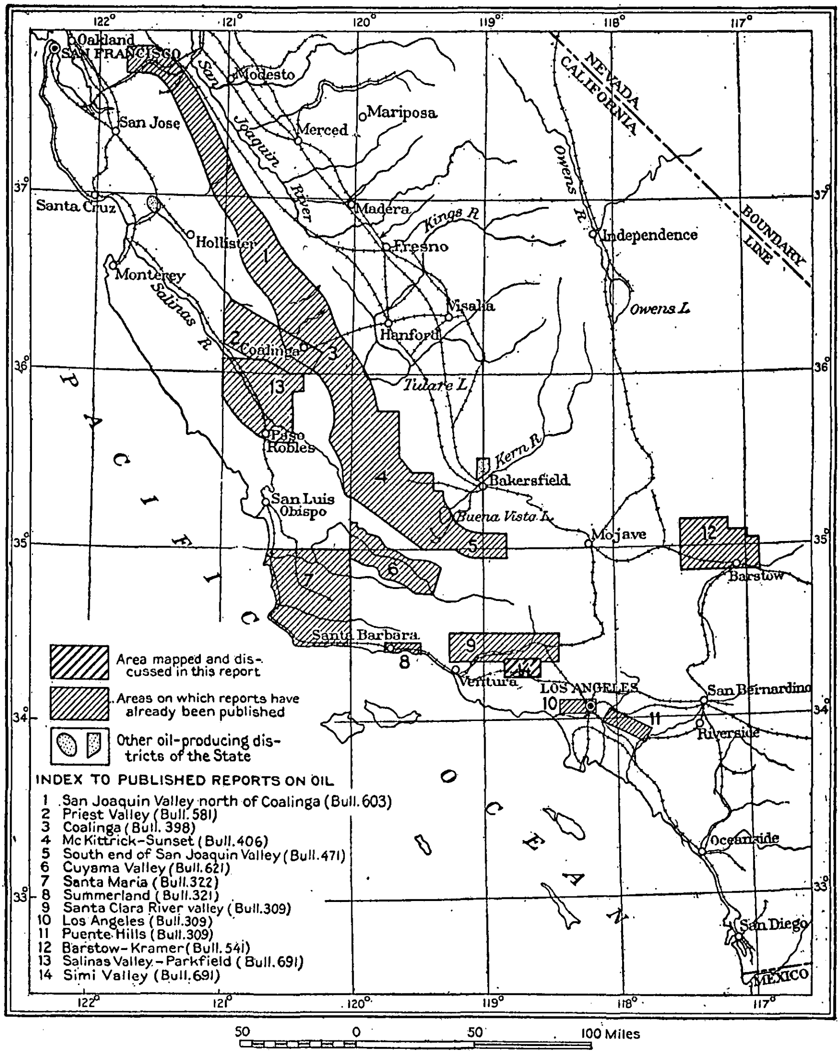


FIGURE 45.—Index map of a part of California, showing oil fields discussed in reports published by the United States Geological Survey.

about 35 miles west from the San Gabriel Mountains, gradually becoming lower in altitude. They are composed of sedimentary rocks in which erosion has developed a topography that contrasts strongly with that of the San Gabriel Mountains, which are formed of igneous and metamorphic rocks. The erosion of the clastic rocks of the Santa Susana Mountains has given rise on the north flank to a comparatively rough surface, with sharp ridges and narrow canyons, extending to the Santa Clara Valley from a relatively even crest line at an altitude of about 3,000 feet. The south side of these mountains differs from the north side in that it is much steeper and the ridges are shorter and more rounded in outline. East of the north end of the Simi Hills the lower part of the front slopes gradually for 2 or 3 miles to the San Fernando Valley. From the low ridge between the Santa Susana Mountains and the Simi Hills a depression extends westward, forming the upper parts of Tapo Canyon and Happy Camp Canyon. This depression is separated from the Simi Valley by a low ridge whose gentle southern slope has been cut by numerous small streams into a topography of badland type. The Simi Hills, a rugged mass of sandstone extending from the Santa Susana Mountains south and west, reach an average altitude of about 2,000 feet and border the broad Simi Valley on the east and south. The slope to the valley from the crest of these hills is moderately steep, especially on the east side near Santa Susana Pass. The lowest part of the valley is on the south side, probably because of the deposition at the mouth of Tapo Canyon of a large alluvial fan which covers nearly the whole east end of the valley. Within the mapped area all streams from the south side of the Santa Susana Mountains and the north side of the Simi Hills drain either into the Simi Valley or the San Fernando Valley. On account of the semiarid climate in this region, they are small and intermittent, usually drying up in the fall and rarely flowing beyond the mouths of their canyons, except during the rainy season. Few springs occur in the Simi Hills, but springs are rather numerous on the Santa Susana Mountains, especially along the Santa Susana fault. Many of them are alkaline and charged with hydrogen sulphide. Water can easily be obtained for drilling either from springs or by pumping from shallow wells.

STRATIGRAPHY.

GENERAL SECTION.

All the rocks within the Simi Valley district are of sedimentary origin with the exception of a few small areas of basic igneous rocks of Miocene age. In stratigraphic succession they represent the following formations:

Formations exposed in the Simi Valley district, Cal.

System.	Series.	Group and formation.	Thickness in feet.	Character.
Quaternary.	Recent.	Alluvium.		Sands, gravel, and clay in valley bottoms and along streams.
	Pleistocene.	Terrace gravels.	0-250	Gravel and sands, partly consolidated, forming terraces now dissected; deposits derived from rocks forming the adjacent hills.
		Unconformity		
Tertiary.	Pliocene.	Fernando formation.	1,000±	Lower beds of conglomerate, coarse and fine sandstone, in part fossiliferous; upper beds of relatively unconsolidated gravels and sands, fossiliferous. Probably all Pliocene in this area; top and bottom of formation as developed in other areas are lacking here.
		Unconformity		
	Miocene.	Basic igneous rocks.	150±	Vesicular and dense andesitic lavas and basic intrusive rocks; associated with rocks of Monterey group.
		Monterey group. Modelo formation.	8,700±	Sandstone No. 2, 3,000± feet of coarse brown and tan well-bedded sandstone, often nodular; cut out in eastern part of area by Santa Susana fault. 1,700± feet of clay and diatomaceous shale, somewhat sandy at top. Sandstone No. 1, 2,500± feet of coarse brown to white hard sandstone, locally impregnated with oil. 1,500± feet of diatomaceous shale, in places cherty, with minor intervals of clay shale. No fossils found in the sandstones.
		Monterey group. Vaqueros sandstone.	100-1,800±	Brown conglomerate, coarse sandstone, fine uncemented sandstone, and sandy shale; contain a distinctive lower Miocene fauna.
		Unconformity		
	Oligocene (?)	Sespe formation.	4,000±	Brown to light-gray conglomerate and sandstone, interbedded with varicolored clays and sands; probably of continental origin. No fossils. Oil bearing in middle part.
		Unconformity		
	Eocene.	Tejon formation.	2,000-3,500	Brown to rusty-colored conglomerate, sandstone, and gray shale with calcareous concretions; principal oil-bearing beds within this formation. Fossiliferous.
		Martinez formation.	1,500-3,000	Heavy basal conglomerate, overlain by brown and gray shale with calcareous concretions. Fossiliferous.
		Unconformity		
Cretaceous.	Upper Cretaceous.	Chico formation.	5,500±	Massive brown sandstone with minor beds of gray shale and calcareous sandstone. Calcareous sandstone below massive sandstone contains Upper Cretaceous fossils south of Simi area.

CRETACEOUS SYSTEM.

CHICO FORMATION (UPPER CRETACEOUS).

The greater part of the Simi Hills is composed of rocks of Chico (Upper Cretaceous) age. In the area described in this report the Chico is well exposed west of Chatsworth, in Santa Susana Pass, where the Southern Pacific Railroad tunnel has been cut through it. The section consists of about 5,500 feet of buff or yellowish-brown medium to coarse grained massive sandstone, interbedded with which are minor thicknesses of gray or olive-colored shale, all unfossiliferous. These beds weather out into huge picturesque step-like blocks, which are often used as a setting for moving-picture scenes. Until recently the age of these rocks has been in doubt, though for a great many years Upper Cretaceous fossils characteristic of the Chico formation elsewhere in California have been known to occur in calcareous sandstone and shale lying conformably below these massive sandstones. This series lies unconformably below the Martinez formation (lower Eocene) and is therefore of pre-Eocene age.

TERTIARY SYSTEM.

EOCENE SERIES.

GENERAL FEATURES.

In the Simi Valley district, as in other localities in California, the Eocene comprises both the Martinez (lower Eocene) and the Tejon (upper Eocene) formations. Although these divisions are elsewhere separated by an unconformity, the series, consisting of 3,500 to 6,500 feet of conglomerates, sandstones, and shales of various types, here appears to be homogeneous. The basis of separation is paleontologic, as the upper and lower beds of the Eocene contain distinct faunas similar to those in the Martinez and Tejon of the type localities. Owing to the similarity in lithology between the two formations no definite line of separation could be drawn, but the boundary as shown on the map, determined by the presence in the beds of characteristic fossils, is thought to be accurate within a stratigraphic distance of 50 feet.

MARTINEZ FORMATION (LOWER EOCENE).

Rocks containing a lower Eocene fauna correlated with that found in the Martinez formation as exposed commonly in other parts of the State lie unconformably above the Upper Cretaceous sandstones in the Simi Hills. They crop out in a relatively narrow strip across the south and east sides of the Simi Valley and range in thickness from 1,500 feet in their most easterly exposure to 3,000 feet in the vicinity of Santa Susana Pass. Lithologically the Martinez on the south side of the valley consists of a prominent basal conglomerate 25 to 1,000 feet thick, overlain by massive greenish-brown or dark-brown sandstones and gray to brown shales or sandy shales. Less sandstone is present toward the top of the section, and on the east a large part of the lower sandstone is replaced by shale. North of the valley the lower third of the section is composed of the basal conglomerate and calcareous sandstone, and the remainder is a bluish-gray shale containing calcareous concretions. The formation here is unfossiliferous and is in striking contrast to the beds south of Santa Susana Pass, which yield many Martinez species. Among them are *Turritella pachecoensis* Stanton, *Amauropsis martinezensis* Dickerson, *Cucullaea mathewsonii* Gabb, and *Glycimeris veatchi* var. *major* Stanton.

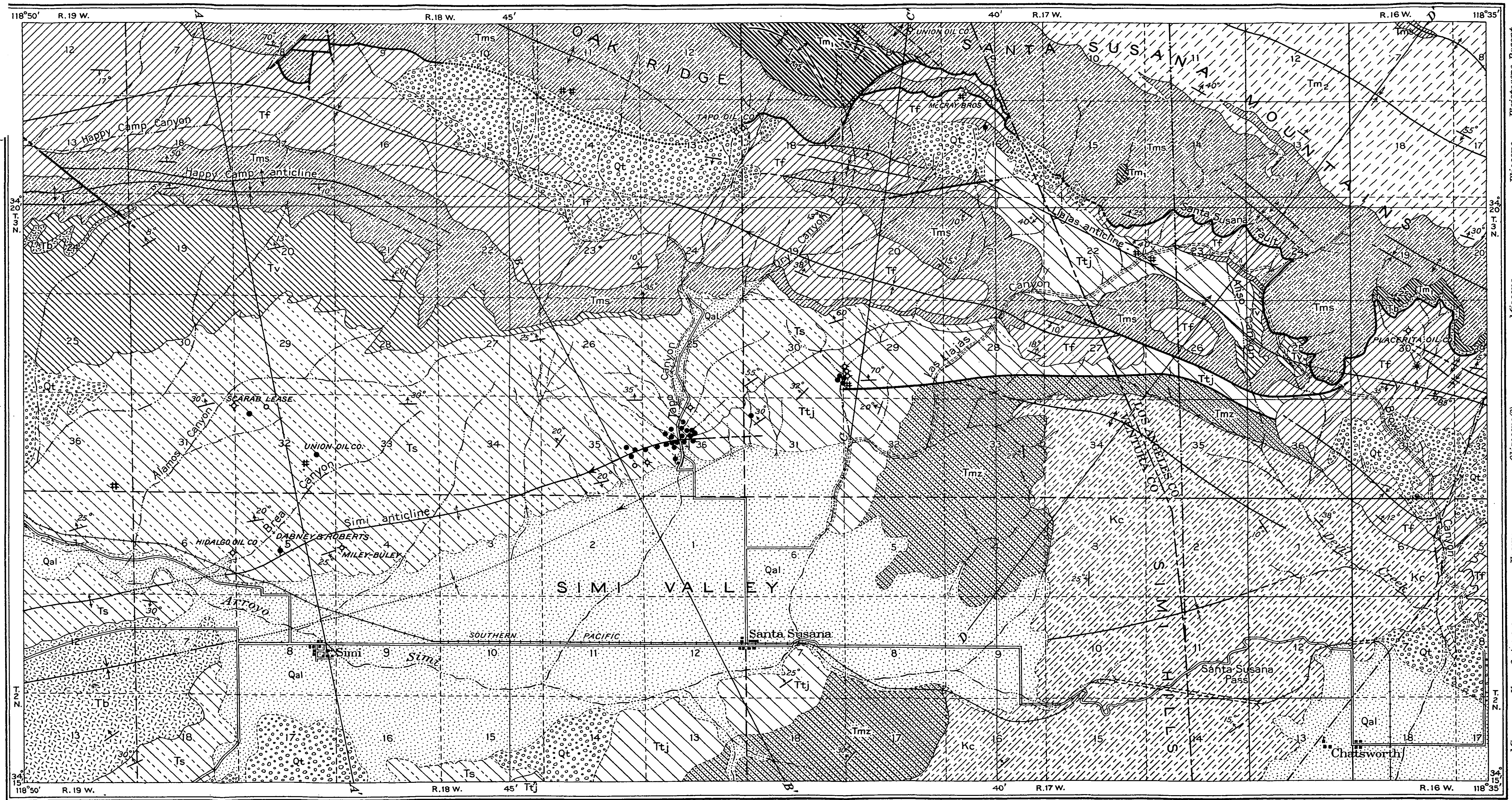
TEJON FORMATION (UPPER EOCENE).

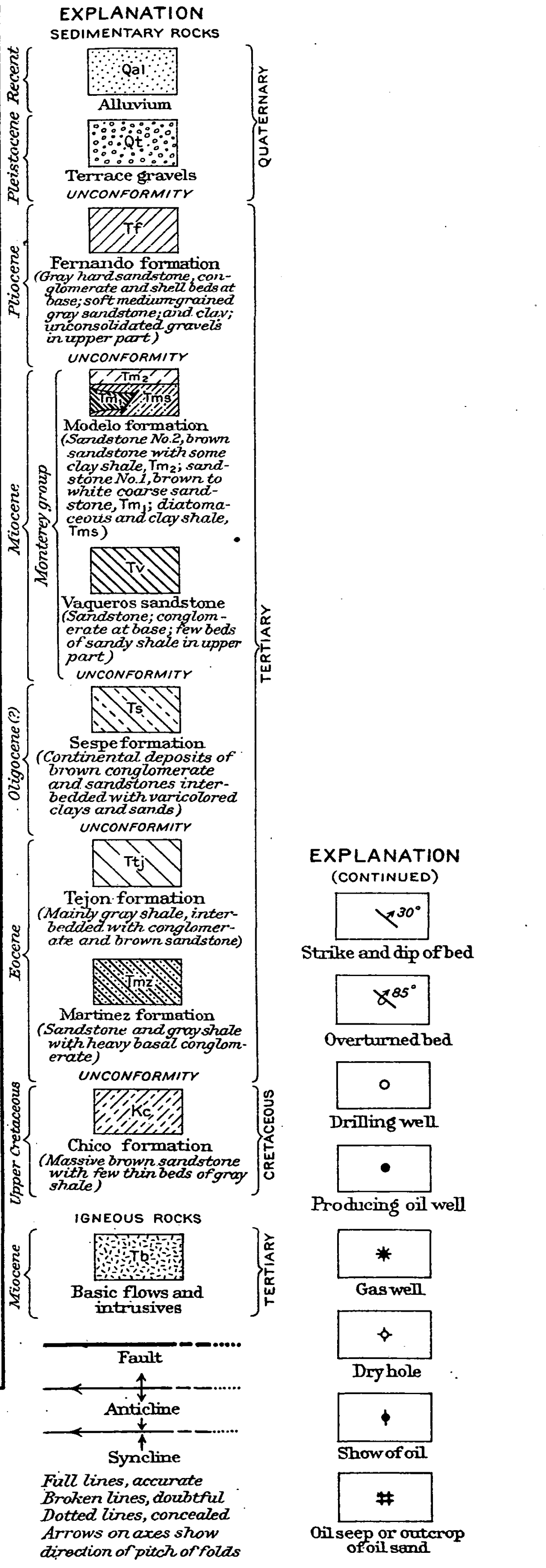
The exposures of Tejon rocks cover a relatively wide area. As shown on the map (Pl. XLI) the Tejon forms the foothills on the south side of the Simi Valley and continues northward to its upper end, where it is covered by later formations. A small strip, faulted on both sides, swings eastward across the north end of the Simi Hills to and beyond Aliso Canyon, where it is overlain by Fernando beds. North of the Simi Hills and at the foot of the steep slope of the Santa Susana Mountains the Tejon is exposed in an irregular lens-shaped area, along the axis of an anticline. From its distribution at the surface it may be assumed that the Tejon underlies a large part of the area covered by the map.

Like those of the Martinez, the strata of the Tejon are more or less lenticular, as is brought out strongly by a study of the well logs. In general, it consists of 2,000 to 3,500 feet of marine shales, sandy shales, sandstones, and conglomerates, and the fine and coarse rocks are distributed in about equal proportions within the area shown on the map. In the westward extension of the area south of the Simi Valley a large part of the shale grades laterally into a rather coarse massive brown sandstone which forms prominent outcrops in this region. The shales are usually of a bluish or olive-gray color, and with them are interbedded sands and sandy shales, together with a few beds of harder calcareous sandstone or strata containing calcareous concretions. Most of the sandstone and conglomerate occurs in the lower part of the series. A generalized section near the mouth of Llajas Creek and northward is as follows:

Section of Tejon formation near mouth of Llajas Creek and northward.

	Feet.
Fine-grained muddy sandstones, sandy shales, and olive-colored shale, with a few hard beds of sandstones; fossiliferous	1,700
Conglomerate and medium-grained quartzitic sandstone	1,100
Fine gray to rusty-colored sandstones and sandy shales, with beds of dark-brown calcareous sandstones containing fossils	1,100
Coarse brown conglomerates of quartzite boulders, averaging 6 inches in diameter, with lenses of fossiliferous sandstone	240
Soft sandy shales, grading upward from the Martinez shales below	275
	4,415





Base from Santa Susana and Camulos topographic maps

GEOLOGIC MAP OF SIMI VALLEY, VENTURA COUNTY, AND PART OF LOS ANGELES COUNTY, CAL.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Geology by W.S.W. Kew assisted by C.M.Wagner

Scale $\frac{1}{62,500}$

1 ½ 0 1 2 3 Miles

1918

In the lens-shaped area of the Tejon near the headwaters of Aliso and Llajas creeks are exposed about 200 feet of strata consisting of light-brown, gray, or bluish soft fine-grained sandstone not well consolidated except for some lenses and concretions of fossiliferous hard brown calcareous sandstone. Where these beds are associated with the overlying Fernando formation, which is in many places of similar lithology, the separation of the two formations would be difficult were it not for the fossils which are usually present in both formations. Lying above these beds are bluish and brownish even-grained sandstones interbedded with softer sandy shales in which the bedding is irregular or rare.

OLIGOCENE (?) SERIES.

SESPE FORMATION.

The single area in which the Sespe formation crops out within the region here discussed extends from Llajas Canyon westward beyond the edge of the area mapped for several miles. The formation probably underlies the valley in the vicinity of Simi, for it is exposed on the south side overlying the Tejon formation. From Llajas Canyon, where it is represented only by a thin strip, the outcrop broadens until west of Tapo Canyon it is about 2 miles wide and comprises 4,000 feet of the strata. The Sespe lies with apparent conformability upon the Tejon and consists of light-brown and buff-colored sandstones and conglomerates, interbedded with thin white, purple, red, blue, green, and yellow sands and clays. These colored bands are present throughout the formation but are more numerous in a zone near the middle, as shown by the following generalized section:

Section of Sespe formation on west side of Tapo Canyon.

	Feet.
Upper brown sandstone and conglomerate interbedded with a few bands of colored sands and clays; grade up into Vaqueros sandstone	350
Mainly colored sands and clays interbedded with a few yellow sands; softer and form a more subdued topography	1,500
Lower light-brown sandstones and conglomerate, with interbedded colored sands and clays; form prominent ridges	2,200
	4,050

The rocks of the Sespe as a whole are but slightly indurated, a condition which has allowed relatively rapid erosion and produced a badland type of topography. The brown sandstones and conglomerates, being slightly harder than the varicolored beds, form the ridges and higher areas. The general aspect of these beds suggests that they are of continental origin, and this suggestion is strengthened by the fact that no fossils have been obtained from them. They are regarded as probably of Oligocene age, because of their position between lower Miocene and Eocene rocks.

MIOCENE SERIES.

MONTEREY GROUP.

GENERAL FEATURES.

The Monterey group (Miocene), which in the Simi Valley district is divided into the Vaqueros sandstone and Modelo formation, is one of the most widespread series of rocks in California. It has a remarkable development in the Santa Clara Valley and Santa Susana Mountains region, a relatively small part of which is included within the limits of this report. Eldridge,[1] in his report on the Santa Clara Valley district, separated the rocks now included within the Monterey group into the Vaqueros formation and the Modelo formation, the latter consisting of two sandstone members within a shale. In the present report these names are retained, but the units to which they are applied have been readjusted. The Vaqueros is limited to include only those rocks composed chiefly of sandstone and subordinately of shale with which is associated a lower Miocene fauna characteristic of Vaqueros strata in California. They are the "shales, purplish, rusty, and gray in color, purplish prevailing, perhaps 500 feet" of the lower part of the Vaqueros as described by Eldridge and apparently erroneously indicated on his map as the upper zone of the Sespe formation. The Modelo formation is regarded as essentially a shale, and in the type locality includes the shale lying above the fossiliferous Vaqueros beds and included by Eldridge in the Vaqueros formation. Within the shale are two sandstone members that vary more or less in thickness and lateral extent and are of the nature of large lenses. The shale separating these sandstones also varies in thickness, and at one place near the west end of the Santa Susana Mountains it is entirely replaced by the sandstone. Both Eldridge [2] and the writer are of the opinion that the Modelo is a correlative of the "Monterey" shale or Salinas shale, the latter the shale formation of the Monterey group in the Salinas Valley region.[3] As the Salinas shale has not been traced continuously into the Santa Clara district, and as the lithology in the two areas is somewhat different, the name Modelo formation is retained for the present. Recent stratigraphic work has brought out the fact, both here and in several other districts in California,[4] that the Vaqueros should be included

[1] Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, pp. 12-22, 1907.

[2] Idem, p. 17.

[3] English, W. A., Geology and oil prospects of the Salinas Valley-Parkfield area, Cal.: U. S. Geol. Survey Bull. 691, pp. 228-229, 1918 (Bull. 691-H).

[4] Louderback, G. D., The Monterey series in California: California Univ. Dept. Geology Bull., vol. 7, pp. 177-241, 1913. English, W. A., Geology and oil prospects of Cuyama Valley, Cal.: U. S. Geol. Survey Bull. 621, pp. 191-217, 1915; Geology and oil prospects of the Salinas Valley-Parkfield area, Cal.: U. S. Geol. Survey Bull. 691, p. 227, 1918 (Bull. 691-H). Waring, C. A., Petroleum industry of California: California State Min. Bur. Bull. 69, pp. 385-386, 1914.

within the Monterey group, and this classification has been adopted by the United States Geological Survey. In the area shown on the map all the units are present and compose the greater part of the Santa Susana Mountains.

VAQUEROS SANDSTONE (LOWER MIOCENE).

The Vaqueros sandstone, which contains a distinctive lower Miocene fauna, has been recognized in two areas within the region shown on the map. The larger of these extends from Tapo Canyon westward nearly to the lower part of Happy Camp Canyon. From a thickness of about 100 feet near Tapo Canyon it attains within a short distance to the west a thickness of about 1,800 feet. There is no angular discordance between the Vaqueros sandstone and the overlying lower shale of the Modelo formation, and it is thought that the eastward thinning and final pinching out of the formation is due to an overlap of the shale. The Vaqueros in its thickest section includes conglomerate beds at the base, overlain by brown, bluish-gray, and rusty-colored sandstones, some of which are micaceous and calcareous. In their upper part the shale become finer grained and lighter in color and include few beds of sandy shale. At several horizons occur fossils that are characteristic of the Vaqueros in California, among which are *Turritella ocoyana*, *Pecten lompocensis*, and *Ostrea vaquerosensis*. The other area of outcrop is in Aliso Canyon, where the Vaqueros lies with a marked unconformity on the Tejon formation. About 250 feet of coarse yellow, brown, and gray sandstone is exposed here, containing *Turritella ocoyana*, *Dosinia ponderosa*, and a few other Miocene fossils, and these sands are interbedded with beds of soft, punky, fine brown sandstone.

MODELO FORMATION (MIDDLE MIOCENE?).

The Modelo formation within the limits of the area mapped (Pl. XLI) is an extension of the type section of this formation, except that the lower member of the Modelo as here delimited was mapped by Eldridge[1] as Vaqueros, and the upper shale member described by him is not present in the Simi Valley. Southward across Santa Clara River all the Modelo west of Torrey Canyon was mapped by Eldridge as Vaqueros. The Modelo forms the greater part of the Santa Susana Mountains and Oak Ridge and is also exposed in a few areas to the south, where the shale crops out in a zone extending westward from Aliso Canyon beyond the area shown on the map. In this region the lower part of the Modelo consists of a diatomaceous shale overlain by two massive sandstone beds that are usually separated by diatomaceous and clay shales.

[1] Eldridge, G. H., op. cit., pl. 1.

The intervening shale body grades laterally into the sandstones immediately north of the border of the area mapped, at the west end of the Santa Susana Mountains, so that the section on Oak Ridge really consists of but one shale and one sandstone body. The shale that overlies the upper sandstones in the type locality is absent south of Santa Clara River.

Although the lower sandstone composes a large part of the Modelo formation, especially on the north side of Oak Ridge, comparatively little of it crops out in the area here discussed. Between Oak Ridge and the Santa Susana Mountains a body of highly folded and crumpled sandstone lies stratigraphically between the shales of this formation. The Santa Susana fault abruptly terminates the sandstone in Dry Canyon, but it is again exposed along this fault in a narrow strip at the head of Browns Canyon. It consists of about 2,500 feet of massive coarse sandstone interbedded with thin bands of dark clay shale, though at some horizons it is almost a pure-white quartzitic sand with occasional beds of grit or conglomerate. A characteristic feature of these sandstones is the presence of many dark-colored calcareous nodules about a foot in diameter, which on weathering fall out and give the surface of the rock a pitted appearance. For the most part the sandstone is of a dark-brown color, often oil stained, which contrasts strongly with the much lighter colored diatomaceous shale.

The upper sandstone is exposed only in the northeast corner of the area under consideration but is well developed on the north side of the Santa Susana Mountains, where its greatest thickness is about 3,000 feet. It consists in large part of massive brown to nearly white and rusty-colored coarse sandstone beds and forms a very rugged surface, with steep ridges and deep, sharp canyons. Conglomerate and shale beds are locally present but constitute a minor part of the formation. Both sandstones are covered by a dense growth of chaparral, whereas the shale is either nearly barren or supports only a light growth of sage or grass with a few oak trees.

Lithologically the shale of the Modelo formation is similar to the bituminous or diatomaceous shale which occurs in many other places in California, and from which it is believed that a large part of the California oil has been derived. Under the microscope or hand lens this shale is seen to contain the skeletons of a great number of the minute organisms known as diatoms and foraminifers, and some of the rock is composed almost entirely of these remains. Its color is usually light, nearly white or creamy, though locally it may be pinkish and, when burned, a brick-red. Under ordinary conditions the beds are soft, powdery, and flaky, but commonly large areas of the rock have been silicified into a hard, brittle, thin-bedded or laminated cherty rock, usually contorted, broken, and weathered into small rectangular blocks that litter the surface of the ground. Shale of this hard type forms a large part of Oak Ridge. Limestone bands or lenses are in many places associated with the shale of both varieties. The thickness of the shale is subject to considerable variation but is usually 1,500 feet or less. The shale that crops out on the top and south flank of the Santa Susana Mountains north of the Santa Susana fault is closely allied in composition to the shale of Oak Ridge. The lower part consists of about 1,700 feet of light-colored hard siliceous diatomaceous shale but toward its top grades into a less distinctly bedded chocolate-colored clay shale containing yellow limestone lenses and concretions. The uppermost 200 feet is of this character but is somewhat more elastic, containing interbedded layers of fine sandstone. This area of shale as a whole can not be traced west of the Santa Susana Mountains on the north side of Oak Ridge, for the beds in that direction laterally become more sandy and finally pass into fine-grained sandstones interbedded with dark clay shales.

PLIOCENE SERIES.

FERNANDO FORMATION.

The Fernando formation is exposed in a series of irregular areas along a synclinal region between the Santa Susana Mountains and the Simi and San Fernando valleys. It lies with a marked unconformity on all the older formations, as the mapping of its boundaries clearly shows. Owing to the irregularity in distribution its thickness ranges from a few hundred feet where it caps the hill between Aliso and Llajas creeks, to about 1,000 feet in Tapo Canyon, and probably it has the same thickness in Browns Canyon. On the south side of the Santa Susana Mountains the Fernando is composed entirely of sandstone and conglomerate; the latter makes up the upper part of the formation. The basal part of the Fernando usually consists of coarse sandstone, in places conglomeratic, with one or more "reef" beds made up either of coarse sandstone or, as in the Tapo Canyon region, almost entirely of shell fragments. Rock of the latter type is used locally for lime after burning. Above this is a series of soft brown sandstones, usually unfossiliferous, which in turn are overlain by the gravels of the uppermost beds of this formation. The lower sandstone as exposed in this region is very fossiliferous, and the following species among others were collected from it in Browns Canyon below the abandoned wells:

Pecten ashleyi Arnold.
Pecten opuntia Dall.
Pecten cerrosensis Gabb.
Lucina sp.
Anomia sp.
Schizotherus or Saxidomus sp.

Solen sicarius ?
Metis? alta Conrad.
Ostrea veatchi Gabb.
Neverita recluziana Petit.
Margarita sp.
Dendraster excentricus var. diegoensis Kew (MS.).
Terebratalia smithi Arnold.
Terebratalia sp.

The fauna is of Pliocene age but later than that found in the lowest Fernando beds near Newhall and considered by English[1] to be lower Pliocene. The equivalents of these older beds are not present in the Simi area. That the Fernando beds of the Simi area are all pre-Pleistocene is believed from the fact that they have suffered a high degree of deformation and are overlain unconformably by well-dissected terraces of probable Pleistocene age.

QUATERNARY SYSTEM.

TERRACE GRAVELS AND ALLUVIUM.

Along the foothills and at the base of the steep front of the Santa Susana Mountains are irregular-shaped patches of loosely consolidated gravel derived from the diatomaceous shale and associated rocks that form the mountains. Other terrace gravels are present south of the Simi Valley, at the foot of the Simi Hills, but they lie at a lower altitude and are less deeply dissected than those north of the valley. These deposits, which accumulated during the Pleistocene epoch, at one time probably formed a continuous belt across this region, but subsequent erosion has left only remnants. They vary markedly in thickness but at many points reach an estimated thickness of 250 feet. Since the deposition of these beds a gradual filling of the Simi and San Fernando valleys has been going on, and the later deposits of gravel, sand, and clay have piled up to considerable depth. Neither the terrace deposits nor the alluvium are important in relation to petroleum, but they effectively conceal the geology of the older rocks beneath and are capable of hiding structure that might be favorable for the existence of oil reservoirs.

IGNEOUS ROCKS.

West of Simi a series of andesite and basalt (?) flows, which includes both vesicular and dense types, overlies the Sespe formation in the shallow depression formed by the Simi Valley syncline. These rocks are continuous with the great mass of andesite, basalt, dacite, and andesite breccia and mud flows that cover a large area to the southwest in the vicinity of Conejo Valley and the western part of the Santa Monica Mountains.

[1] English, W. A., The Fernando group near Newhall, Cal.: California Univ. Dept. Geology Bull., vol. 8, pp. 203-218, 1914.

A basic igneous rock is exposed in two other small areas within the region under discussion. In these areas the rock is intrusive into the Vaqueros and the lower sandstone of the Modelo formation, where they crop out on the ridge south of Happy Camp Canyon and at the head of Browns Canyon, as a narrow strip along the Santa Susana fault. The igneous rock is greatly weathered, but from fairly fresh pieces it appears to be either a basalt or a diabase, and it is probably closely allied to the great mass of volcanic rocks mentioned above.

STRUCTURE.

GENERAL FEATURES.

The structure, or attitude of the different strata in the Santa Susana Mountains and Simi Valley is closely related to that of the California Coast Range, which is characterized by a number of northwestward-trending folds, broken by faulting. South of San Joaquin Valley the direction of the structural axes is more nearly west than along the west side of that valley, and these axes are reflected topographically in the Santa Ynez, Santa Susana, and Santa Monica mountains. The forces causing this deformation have been at work throughout many geologic ages but the Coast Ranges, as they are seen to-day, were brought into relief by movements which occurred mainly during Pliocene and Pleistocene time, although occasional earthquakes indicate that these deformative movements are still taking place.

The Simi Valley oil district (see Pl. XLI) lies in the midst of the westward-trending ridges of the Coast Ranges and embraces a part of two large structural features, the Santa Susana Mountains and the Simi Hills. In this region the dominant structure is a result of compressive forces which acted from north to south at the end of the Pliocene epoch. Evidence of pre-Pliocene movements is present in the marked unconformity between the rocks of the Monterey group and those of the Fernando formation. The Santa Susana Mountains owe their existence, at least in part, to folding begun at this time, but they have been considerably modified by subsequent compressive movements, at the end of the Pliocene. The time of formation of the Simi Hills can not be definitely stated, as the rocks of the Monterey group are the latest series involved, but it is likely that forces acting from the end of the Sespe epoch (Oligocene?) to recent time have affected this region. Slight post-Pliocene folding is indicated in the gentle warping of the older terrace deposits along the southern foot of the Santa Susana Mountains.

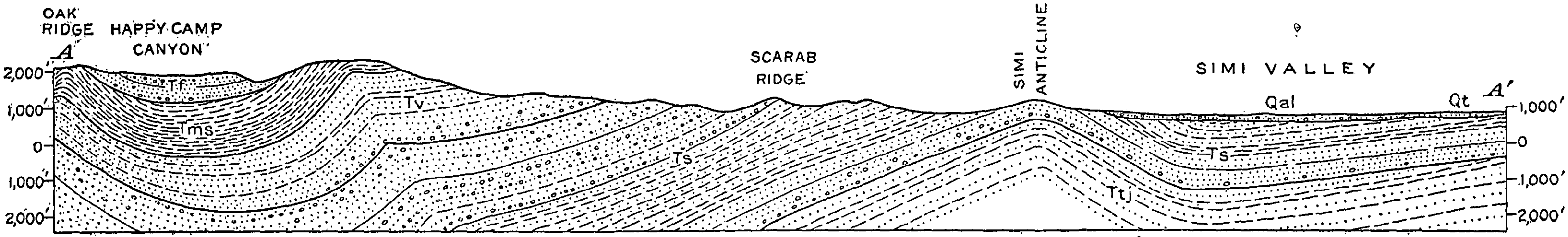
The principal structural feature in the Simi district is the Santa Susana fault (see Pl. XLI and sections C–C′ and D–D′, Pl. XLII), which follows closely the foot of the steep southern front of the Santa

Susana Mountains, extending from a point just west of San Fernando Pass to a point on the south side of Oak Ridge at the head of Happy Camp Canyon directly south of Torrey Canyon. This fault is of the reverse type and has caused the rocks of the Monterey group to be shoved over those of the Fernando formation. North of the fault the Monterey rocks which compose most of the Santa Susana Mountains form the south limb of the great syncline underlying the upper Santa Clara Valley. South of the fault the principal structure is a synclinorium (see sections A–A′ and B–B′, Pl. XLII), the south limb of which forms the Simi Hills. The north limb of the synclinorium forms the south side of Oak Ridge and is cut off on the east by the Santa Susana fault. Within this trough are several minor folds, some of which, in the area between the Santa Susana Mountains and the Simi Hills, are modified by faulting. The principal folds are the Simi anticline, extending along the north side of the Simi Valley and the Tierra Rejada, and the Llajas anticline, a prominent fold south of the Santa Susana fault, traceable from Browns Canyon northwestward to Oak Ridge. The two large synclines are present in this area and form structural valleys. The northern one follows Happy Camp Canyon and the upper Tapo Canyon basin and finally dies out on the divide between the Simi and Fernando valleys. The southern syncline parallels the Simi anticline on the north side of the Simi Valley and continues westward through the Tierra Rejada. All of the folds converge toward the area between the Santa Susana Mountains and the north end of the Simi Hills (see Pl. XLI), where the beds dip steeply and are faulted. These faults appear to separate the complex structure prevalent in the Santa Susana Mountains from the comparatively simple structure of the Simi Hills.

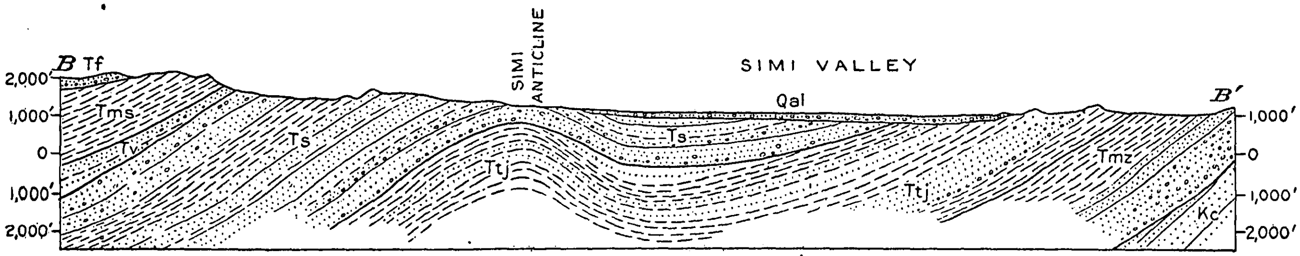
LOCAL DETAILS.

In the detailed discussion of the structure of this region only the features relating more or less closely to the oil resources of the area covered by the map will be described—in other words, the structural features lying south of and including the Santa Susana fault.

The Santa Susana fault is distinctly of the reverse type—that is, the older beds have been forced up and over the younger. (See sections C–C′ and D–D′, Pl. XLII.) The greatest movement took place in the region between Browns and Dry canyons, where the plane of the fault dips as low as 5° N. and the Monterey (Miocene) beds have been shoved over the Fernando (Pliocene) strata. Both to the west and east the angle of dip of the fault plane becomes larger. At the head of Happy Camp Canyon the plane is vertical, but beyond that point the stresses appear to have been relieved through folding instead of faulting. In the region of greatest displacement the strata have been broken, and in the Fernando formation several acute folds have been formed, which in places are over-



SECTION ALONG LINE A-A′



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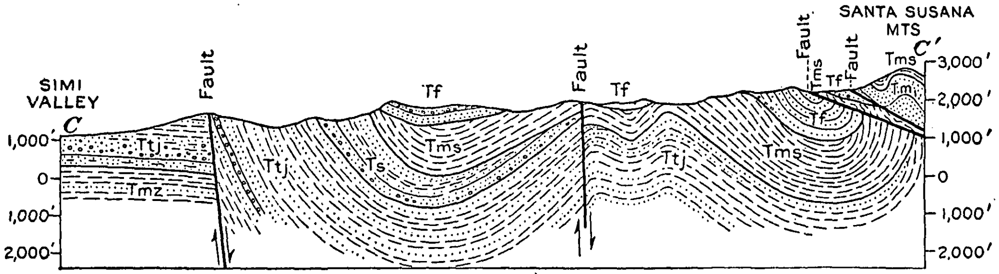
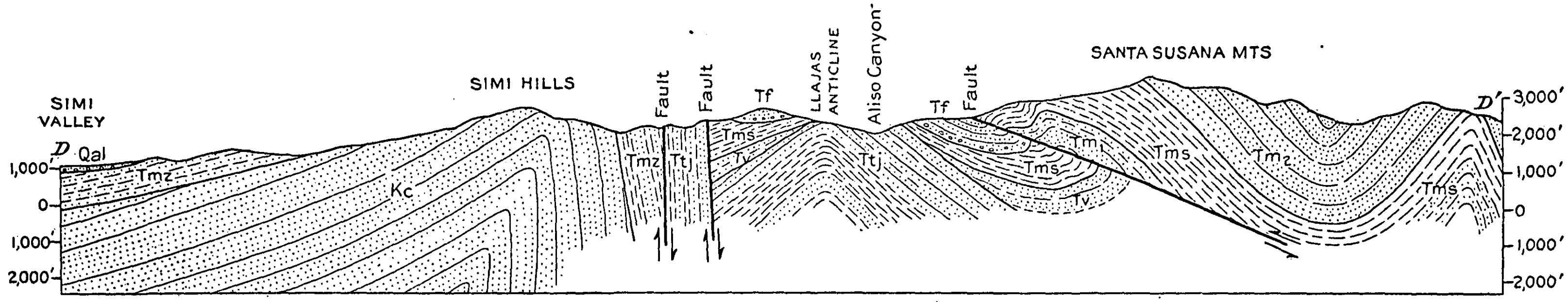
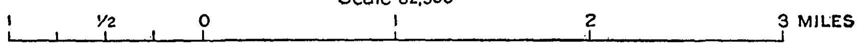


SECTION ALONG LINE C-C′

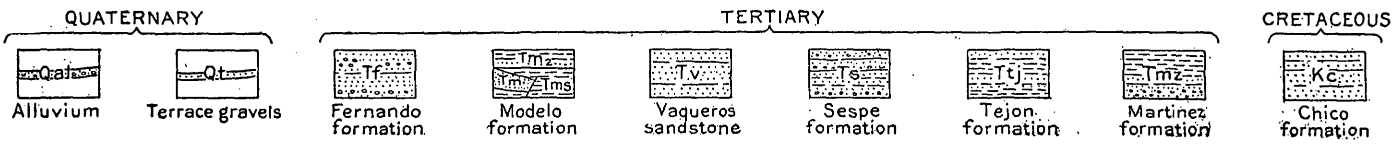


SECTION ALONG LINE D-D′

Scale $\frac{1}{62,500}$



EXPLANATION



STRUCTURE SECTIONS IN SIMI VALLEY, CAL.

For lines of sections see Plate XLI.

turned to the south. Near the head of Llajas and Aliso canyons the large Llajas anticline brings up the Tejon formation flanked by the Vaqueros formation, the lower shale of the Modelo formation, and the Fernando formation. (See section D–D′, Pl. XLII.) The overlapping of the Tejon by the younger beds is much more abrupt to the east on account of its unconformity with the overlying beds of the Monterey and Fernando, and in Browns Canyon the anticline is entirely within the Fernando strata, which are acutely folded and in places overturned toward the south, no doubt owing to the pressure exerted at the time when the Santa Susana fault was formed. West of Aliso Canyon the anticline plunges gently westward, exposing the Tejon strata for about 3 miles in that direction. About half a mile west of the county line a small cross fault apparently terminates this fold, although in Dry Canyon there are two small anticlines and a syncline, one of which may be a continuation of the Llajas anticline.

The syncline in Tapo Canyon is one of the major structural features and is the longest fold in this region, extending from the north end of the Simi Hills west down Happy Camp Canyon nearly to the head of Grimes Canyon, beyond the edge of the mapped area, a distance of about 15 miles. In Tapo Canyon the south limb of this fold, consisting of Sespe, Monterey, and Fernando beds, is very broad, reaching nearly to the edge of Simi Valley, where it forms the north limb of the Simi anticline. Farther west, on the south side of Happy Camp Canyon, a very strongly asymmetric anticline with a shallow complementary syncline is developed. The north dip of the anticline is as high as 50°. On the other hand, the beds on the south are nearly flat, so that the syncline, which is very close to the anticline, is hardly perceptible. This gives the structure the appearance of a monoclinal fold. (See section A–A′, Pl. XLII.) The Simi anticline is economically the most important structural feature in the Simi region at the present time on account of its association with the Simi oil field. It has an unbroken length of about 11 miles, extending in a southwesterly direction from a point just east of Tapo Canyon to the Tierra Rejada, about a mile west of the area mapped and 1½ miles south of Moorpark. It is a rather low fold in beds of the Sespe formation which envelop a projecting nose of Eocene strata at Tapo Canyon. The anticline (see sections A–A′ and B–B′, Pl. XLII) is low and flat topped and plunges gently to the west. Although it is comparatively symmetrical near Tapo Canyon, farther west the dip on the south limb becomes steeper than that on the north limb until at the edge of the mapped area the Sespe sandstones on the south dip as high as 50°. The strata on the north side of this fold have a rather uniform attitude, dipping from 20° to 35° N.; the gentler dips occur toward the west. What may be a continuation of the Simi anticline, or at least of the axis of general folding, is the anticline in the Chico and Eocene beds at the north end of the Simi Hills. This fold, which is asymmetric, plunges steeply to the west and is truncated by the east-west fault that crosses Llajas Canyon.

The Simi Valley, a structural as well as a topographic depression, has resulted from the erosion of the northward and westward dipping Cretaceous, Eocene, and Sespe beds which form the Simi Hills. The main synclinal axis of the Simi Valley begins near the mouth of Tapo Canyon and follows the north side of the valley, paralleling the axis of the Simi anticline. Like the anticline, the syncline is an asymmetric fold. The south limb dips much more gently than the north one, is broader, and underlies most of the valley. Another syncline, which is short and broad and plunges steeply westward, crosses the Simi Hills near Santa Susana Pass, but it is not traceable beyond the Chico beds into the Eocene formations.

PETROLEUM.

CONDITIONS OF OCCURRENCE.

In order to form any conclusions regarding the oil possibilities of a new region or to make recommendations for the extension of a partly developed field, it is first necessary to consider the conditions of origin and accumulation of the oil in neighboring districts. As the object of this paper is to make recommendations bearing on both developed and possible new territory in the Simi Valley, the conditions under which the oil occurs in the fields situated on the flanks of the Santa Susana Mountains and Oak Ridge will be briefly reviewed.

The petroleum occurring in these fields is of two types—(1) the oil associated with the Eocene and Sespe formations, which was probably derived from the Eocene shales and migrated upward and laterally into the interbedded sands and sandy shales; (2) the oil associated with the strata that lie above the Sespe formation, which was probably derived from the organic shales of the Modelo formation and later migrated into the more porous strata of the Modelo and Fernando. Regardless of its origin, the oil in nearly every field is confined to a relatively limited area along anticlinal folds.[1]

The Bardsdale, Montebello, and Torrey Canyon fields, on the north side of Oak Ridge, south of Santa Clara River, derive their oil from sands in the Sespe formation, the oil apparently having originated in the Eocene shales and migrated upward and laterally, probably under the influence of either water or capillary action or both, to the tops of domelike uplifts which form the highest areas along the Oak

[1] The accumulation and origin of the oil in California fields is discussed in detail by Robert Anderson and R. W. Pack in U. S. Geol. Survey Bull. 603, 1915.

Ridge anticline. The oil is trapped here in the porous sands of the Sespe formation, which are usually in the form of lenses interbedded with impervious layers of clay, shale, or "shell."

The fields on the north side of the Santa Susana Mountains, east of the Torrey Canyon field, belong to the second type. At Pico and Wiley canyons the oil has migrated from the shale of the Modelo formation into the sandstone strata between the shales and accumulated along the crest of the Pico anticline. At Elsmere Canyon the petroleum is obtained from Fernando (Pliocene) beds, which rest on the metamorphic rocks of the San Gabriel Range. The oil evidently has come from the Modelo shales, exposed near by below the Fernando, and has collected in a steeply plunging anticline. A different mode of occurrence, but of the same type, is represented by the wells in Tapo and Eureka canyons, where the oil is obtained in steeply dipping sandstone beds of the Modelo formation.

SURFACE EVIDENCES OF PETROLEUM.

Oil seeps, brea deposits, or outcropping oil-stained sands in a region show that petroleum is present in certain strata of that region. These indications of oil do not prove that paying quantities of oil may be found by drilling, but they are positive evidence that oil is present, and if the structural conditions involving the oil-bearing strata are favorable there is a fair degree of certainty that oil may be obtained. However, in undeveloped territory the only proof of the presence or absence of petroleum rests in the drill.

At least two small live oil seeps occur in Llajas Canyon close to the line between secs. 22 and 23, T. 3 N., R. 17 W. The oil, which is derived from the Eocene strata, seeps from sandstone beds situated approximately on the axis of the Llajas anticline. These seeps are small, but enough oil has run out to extend several hundred feet down a small gulch. Sands impregnated with oil have been reported in Aliso Canyon near the axis of this anticline.

Large oil seeps and brea deposits are present at the group of wells owned by the Santa Susana Syndicate in the SE. $\frac{1}{4}$ sec. 30, T. 3 N., R. 17 W. The oil at this locality originated from Eocene strata and rose to the surface along the fault and through steeply dipping beds of sandstone and conglomerate. The presence of these seeps was the incentive for drilling in the Tapo Canyon region. Oil sands, from which oil seeps, crop out at several places in Brea Canyon in sec. 32, T. 3 N., R. 18 W., and west of Alamos Canyon in the southeast corner of sec. 36, T. 3 N., R. 19 W. These sands are in the Sespe formation interbedded with colored clays, and it is from these strata that the Scarab wells and the Union Oil Co.'s well in Brea Canyon obtain their oil.

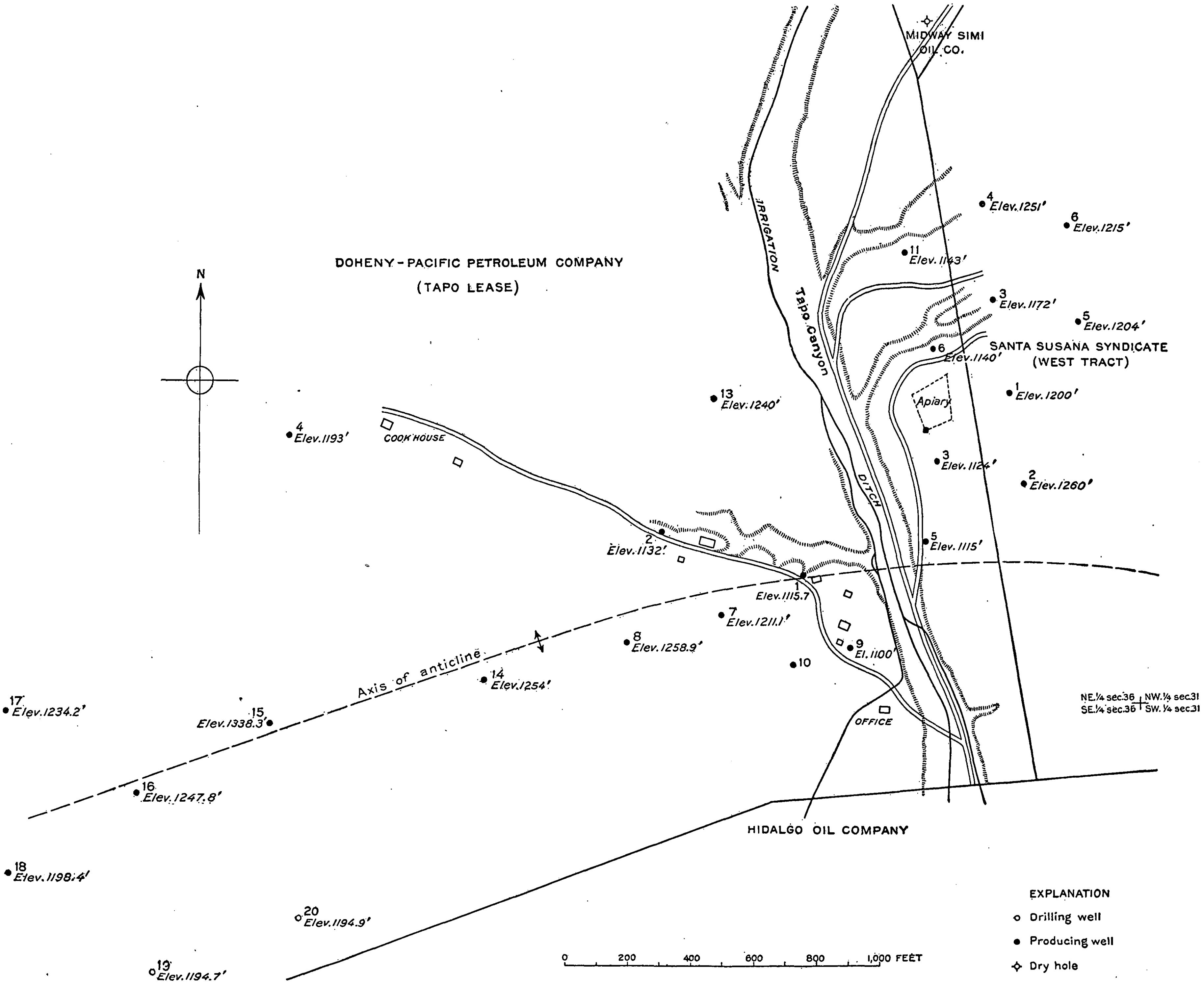
The largest seeps and brea deposits of this region occur at many places along the base of the Santa Susana Mountains, where the oil evidently comes up along the fault at the foot of the mountains or through the lower sandstone in the Modelo formation. These oil-bearing sands are important only in their relation to the fields in the Santa Clara Valley.

PRODUCING WELLS.

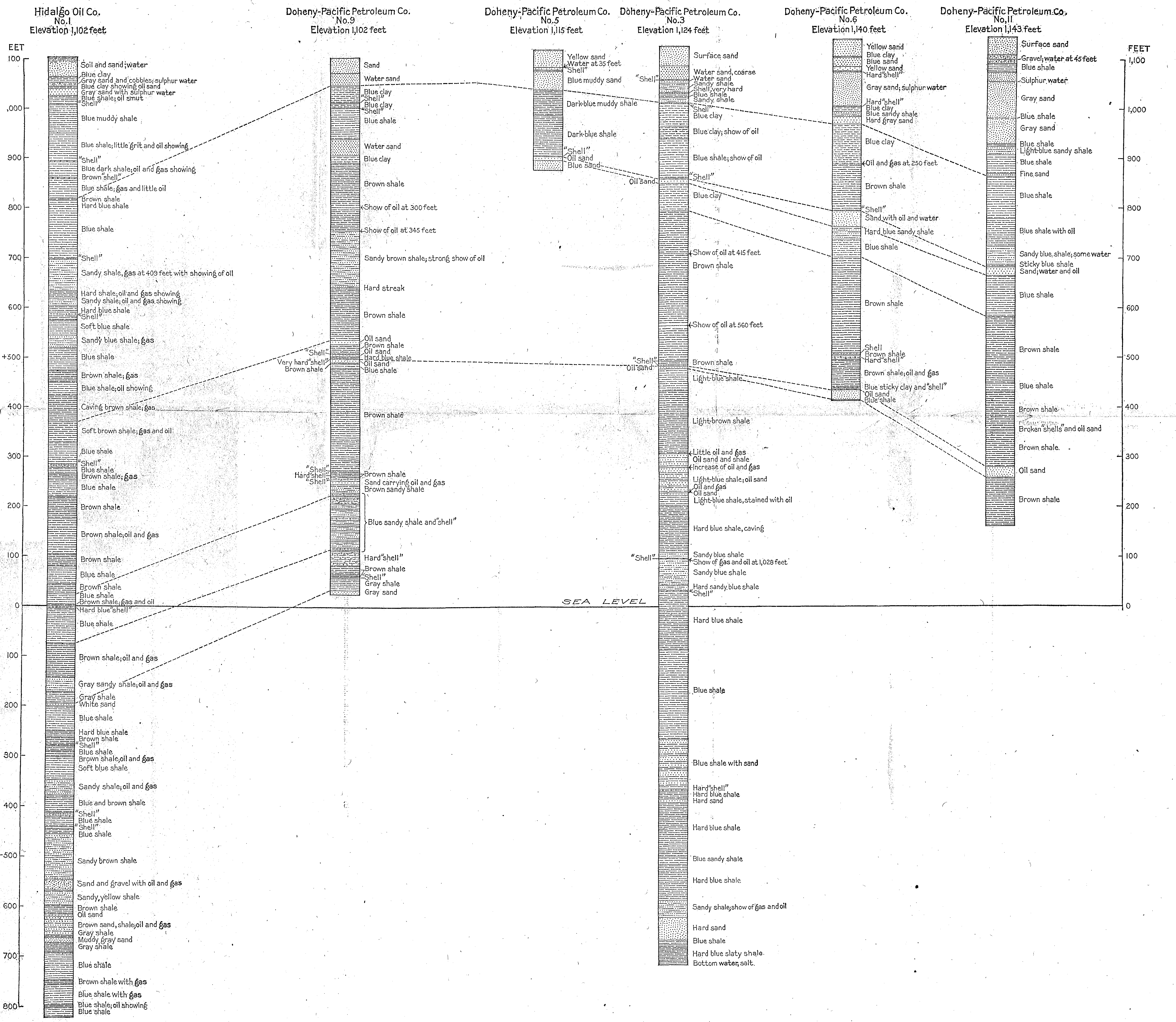
TAPO CANYON FIELD.

All the producing land in the Tapo Canyon field (see Pl. XLIII) is owned by the Doheny Pacific Petroleum Co. (formerly the Petrol Co.) and the Santa Susana Syndicate. The line between the properties of these companies passes up Tapo Canyon, the former company controlling that to the west and the latter that to the east. The wells of the Tapo Canyon field are situated on the east end of the Simi anticline, east of the mouth of Tapo Canyon, where the anticline flattens out into the northwestward-dipping Eocene strata. Nearly all the producing wells are in the SE. ¼ sec. 35 and the central western part of sec. 36, T. 3 N., R. 18 W. The field is now being extended toward the southwest in sec. 35, but further attempts will probably be made to develop the territory lying east of Tapo Canyon. Most of the wells are started in the Sespe (Oligocene?) formation or close to the contact with the Tejon and are drilled into the Tejon formation to reach the productive sands in its upper part. In the western part of the field, where the Sespe is several hundred feet thick, it contains lenticular oil-bearing sands, but the two principal oil sands are in the Tejon, one about 180 feet below the base of the Sespe and another about 550 feet below. The total depth of the sands below the surface varies according to the thickness of the Sespe formation, which increases both to the west, owing to the plunge of the anticline, which averages 10°, and also away from the axis or highest part of the fold. In calculating the depth of the sands below the surface the altitude of the surface at each well is especially important in this region, where a difference in altitude of over 100 feet between wells a few hundred feet apart is common.

A study of the well logs of this field (Pl. XLIV) indicates that there is a distinct lack of similarity in detailed lithology. This is especially true in the Sespe formation, though, in general, a rather sharp break is shown at the contact of the Sespe with the Tejon, the Sespe being composed of coarse sands and clays, while the Tejon is mainly shale, both blue and brown, with small beds of sand and thin "shells" or calcareous beds. The oil strata themselves show irregularities, and it is often difficult to correlate the sands of two neighboring wells. This may be due either to poor drilling records or to the



SKETCH MAP OF TAPO OIL FIELD, SIMI VALLEY, CAL.



LOGS OF WELLS OF THE DOHENY-PACIFIC PETROLEUM CO. AND THE HIDALGO OIL CO. ALONG AN APPROXIMATELY NORTH-SOUTH LINE ACROSS THE SIMI ANTICLINE.

lenticularity of the sands. The latter cause seems to be the more probable, as the lenticular habit of the beds is at many places apparent on the surface. This character is more marked in the Sespe than in the Tejon, as the water sands and oil sands of the Sespe, if present, are rarely continuous from one well to another, and where they are the thickness is never the same.

The more productive wells, according to the records, appear to be either along the axis of the anticline or immediately north of it. The Hidalgo Oil Co.'s well, drilled to a depth of 1,925 feet, about 700 feet south of the axis, never yielded any appreciable amount of oil, and other wells on the south side, although nearer the axis, gave only small amounts. The records of the wells drilled north of the axis indicate that the area of productive territory is much larger on that side, as good wells were obtained more than 800 feet north of the axis, though about 1,600 feet north a dry hole was put down by the Midway Simi Oil Co. An explanation for this difference on the two sides probably lies in the fact that the structure of the south flank is not as favorable for the accumulation of the oil as that of the north flank. From structure section B–B′ (Pl. XLII) it is seen that the axis of the syncline underlying the Simi Valley closely parallels that of the Simi anticline. Although the synclinal axis can not be located exactly, owing to the covering of valley alluvium, the attitude of the beds exposed indicates clearly that the axis is not far south of the edge of the hills. Because of the presence of water in the sands it is extremely unlikely that oil occurs in the syncline. Furthermore, as oil usually migrates upward in the sands, only the small area between the axis of the syncline and the anticline would be available as a source of supply for the oil in the higher areas along the axis of the anticline. On the other hand, the beds on the north limb of the anticline dip northward for several miles, and thus a large area is provided from which the supply of oil might have been drawn. In addition, there is a slight flattening of the beds near the axis on the north side. These conditions would give the north limb of the anticline a larger productive area with richer sands.

At the end of 1917 both companies together were pumping 25 wells, though not all were worked continuously. The field has not yielded a large output and can not be classed with the principal fields of California. During 1917 the Doheny Pacific Petroleum Co. from 12 wells produced 53,000 barrels, and at present the yield is being increased by new drilling, indicating that the field has not yet reached the crest of its production.

The oil ranks among the best in California, averaging about 36° Baumé with a high gasoline content. An analysis made by Dr. Curtiss, of Throop College of Technology, Pasadena,[1] is as follows:

[1] Johnson, H. R., Geologic notes on Santa Susana district: Western Eng., vol. 2, p. 385, 1913.

Analysis of oil from Tapo Canyon field, Cal.

Cut.	Per cent.	Gravity (°Baumé).	Product.
1	10	73.4	Gasoline (36 per cent).
2	10	61.3	
3	6.6	53.5	
4	4.8	50.0	
5	5.2	46.2	
6	6.0	42.2	Kerosene (17 per cent).
7	6.0	38.8	
8	5.0	35.8	
9	4.4	33.0	Distillate (4.4 per cent).
10	10.0	31.3	Lubricants (30 per cent).
11	20.0	33.5	

Another sample tested by Curtiss and Tompkins[1] gave the following results:

Base of oil, asphalt.
Paraffin scale .... per cent.. 1.15
Gravity: Specific 0.8449
Baumé .... 35.7°
Flash point (Tagliabue's open tester) .... Below 14° F.
Fire point (Tagliabue's open tester) .... Below 14° F.
Sulphur .... per cent.. 0.46
Sand and water .... Trace.
Heat value: Calories 10,635
British thermal units 19,144

Fractional steam-distillation test; initial distilling point 111° F.; each fraction 10 per cent:

	Gravity at 60°F.	
	Specific.	°Baumé.
First, up to 217.4° F.	0.6890	73.2
Second, 217.4° to 275° F.	.7372	59.9
Third, 275° to 311° F.	.7688	52.1
Steam introduced.		
Fourth	.7937	46.4
Fifth	.8192	40.9
Sixth	.8552	33.7
Seventh	.8872	27.8
Eighth	.9174	22.6
Residuum or road oil (20 per cent)	.9830	12.4

The above distillation yields commercial products as follows:

	Unrefined products.	
	Per cent.	Gravity (°Baumé).
Gasoline group	20	66.0
Benzine or naphtha	10	52.1
Kerosene stock	20	43.3
Distillate or neutral cut	10	33.7
Lubricating stock	20	25.4
Residue or road oil	20	12.4

The striking features of the oil as shown in these analyses are its high-gasoline content, the large amount of kerosene, and the unusual viscosity of the lubricant products.

[1] Johnson, H. R., Geologic notes on Santa Susana district: Western Eng., vol. 2, p. 385, 1913.

East of Tapo Canyon several wells have been drilled, one in the NW. ¼ sec. 31, T. 3 N., R. 17 W., and seven in the first canyon west of Llajas Canyon, in the SE. ¼ sec. 30. The well in sec. 31 penetrates the northwestward-dipping upper beds of the Tejon formation for 1,500 feet and obtains a small amount of oil from a few sands at a depth of about 1,000 feet. No anticline is discernible in this vicinity. and it is unlikely that the fold continues so far east of Tapo Canyon, A small supply of oil probably migrates up the sands, together with water, as this well yields only 40 barrels of oil a week and pumps 40 per cent water.

The group of wells in sec. 30 were the first drilled in the Simi region, five of these having been put down by the Simi Oil Co. between 1900 and 1902. The wells reached depths ranging from 1,125 to 1,725 feet, and all obtained a small production of light oil (30° Baumé). Four are now pumped at intervals. The wells are on steeply northward-dipping Tejon strata on the north side of an east-west fault. (See section C–C′, Pl. XLII.) This fault dies out before crossing the canyon, and the westward-trending beds on the west side of the canyon swing abruptly to the southwest around the end of the fault. Seeps occur not only along the fault, but the massive sandstone and conglomerate on the north side of the fault are also saturated with oil. The wells were drilled a short distance to the north, evidently to meet these beds, which are the source of their oil. Two other wells put down to a depth of 450 feet by different companies in 1910–11 were abandoned because the holes were crooked. The Santa Susana Syndicate now owns this property.

BREA CANYON AND SCARAB WELLS.

The first wells in the region northwest of the town of Simi were drilled by the Union Oil Co., in Brea Canyon, in the SE. ¼ sec. 32, T. 3 N., R. 18 W., about 500 feet north of an outcropping deposit of oil sand and brea. The first well put down in 1891 was unsuccessful, as was another drilled in 1900, though a show of oil was found at 172 feet. A third well in 1910 reached a productive sand at 770 feet and is now pumped twice a week, yielding 20 barrels of 19° Baumé oil.

The most productive well in this region belongs to what is known as the Scarab lease of the Doheny-Pacific Petroleum Co., in the NE. ¼ sec. 31 and the NW. ¼ sec. 32, T. 3 N., R. 18 W. The first well drilled here by the Scarab Oil Co. never produced, but the second well put down by the same company is at present producing daily about 15 barrels of 19°–20° Baumé oil. The present owners are drilling a third well. These wells are at the base of the upper sandstone and conglomerate member of the Sespe formation, which dip 20°–30° N. and form a part of the north limb of the Simi anticline. (See section A–A′, Pl. XLII.) The producing well, which is 2,593 feet deep, penetrates two oil zones in the colored shale member of the Sespe, one between 1,323 and 1,563 feet below the surface and the second between 1,968 and 2,040 feet. Showings of oil are present at intervals below 1,185 feet, and salt water was struck at 2,500 feet. The oil sands or at least the upper one crops out about half a mile south of the wells, where several large seeps occur.

NONPRODUCING WELLS.

Three wells have been drilled near the mouth of Brea Canyon along the axis of the Simi anticline, starting in the lower sandstone member of the Sespe formation. Two of the wells were put down in 1913–14—one, known as the Dabney & Roberts well, in the NE. ¼ SE. ¼ sec. 5, T. 2 N., R. 18 W., and the other, drilled by the State Consolidated Oil Co. and known as the Miley-Buley well, in the NW. ¼ SW. ¼ sec. 4. A third well in the northeast corner of sec. 6 was drilled by the Hidalgo Oil Co. in 1915. The Dabney & Roberts well, situated on the axis of the anticline, made a good test of this area, going down 2,680 feet. It penetrated the Sespe formation, which is not over 350 feet thick at this point, and probably went through the greater part of the Tejon if not into the Martinez formation, passing almost entirely through shale and sandy shale, with occasional sand strata and "shells." Gas and some oil were encountered at intervals below 315 feet, though none of the sands were rich enough to make the well productive. The Miley-Buley well went to a depth of 1,160 feet, and the Hidalgo well is reported to have gone about 1,925 feet. Neither of these wells struck any paying oil sand, the former not having even reached the Eocene strata.

The Calabasas Oil Co. put down a well in 1914 in the NE. ¼ sec. 13, T. 2 N., R. 18 W., 3 miles southeast of Simi, south of the limits of the area mapped. It was drilled more than 1,900 feet into the northward-dipping Tejon beds which compose the south limb of the syncline under the Simi Valley. It is reported that no oil and but little gas was encountered.

The Tapo Oil Co. is said to have drilled three wells in 1900 and 1901 in the upper part of Tapo Canyon, in the NE. ¼ sec. 14, T. 3 N., R. 18 W. They were less than 700 feet deep, and all were dry holes. They were started in terrace material overlying Fernando beds on the north side of a syncline, south of some seeps that occur in the region along the Santa Susana fault. The location of these wells as shown on the map is only approximate.

Several wells have been drilled near the Santa Susana fault on account of the many seepages and brea deposits that occur along this zone. No oil in paying quantities has been found, although tar beds were usually encountered. The McCray Bros. put down a couple of wells in sec. 13, T. 3 N., R. 18 W., and another in sec. 16, T. 3 N., R. 17 W. The Union Oil Co. had previously drilled one in sec. 9.

Two other wells deserving especial mention are those drilled by Dr. F. C. Melton, of the Placerita Oil Co., in Browns Canyon, in sec. 30, T. 3 N., R. 16 W. One, in the bottom of the canyon, is on the north flank of an anticline in lower Fernando beds, which probably is an extension of the Llajas anticline. No oil was struck, but it is reported that this well produced 1,500,000 cubic feet of gas a day. The second well, on the west side of the canyon, was dry.

FUTURE POSSIBILITIES AND RECOMMENDATIONS FOR DRILLING.

The areas in the Simi Valley region that offer favorable opportunities for expansion of already proved fields or are to be considered as possible new productive territory are confined to the belt between the northern border of the Simi Valley and the foot of the steep slope of the Santa Susana Mountains and Oak Ridge, or south of the Santa Susana fault. It must be borne in mind that no untested area can be proved to be oil bearing by geologic work alone, although the study of different formations and of the structure of the beds may show that certain areas are favorable for the accumulation of oil. The conclusions arrived at in the following paragraphs are to be considered as the individual judgment of the writer.

SIMI ANTICLINE.

The discussion of the oil prospects along the Simi anticline comprises both tested and untested areas and involves the whole region along the north border of the Simi Valley. That oil is present along this anticline is proved in both ends of the fold, but it occurs in paying quantities only at the eastern extremity. This leaves an untested zone extending along the axis of the anticline for nearly 3 miles. It is regarded as highly probable that productive wells can be put down west of the area within which the present operations are confined, and it is recommended that test holes be drilled on the axis of this fold, preferably in the SW. ¼ sec. 35 and the SE. ¼ sec. 34, T. 3 N., R. 18 W. The eastern part of the anticline is regarded as the most favorable, for the fold plunges toward the west. Furthermore, better results are likely to be had astride the axis and on the northern or gentler slope, for the reasons given in the discussion of the Tapo field (p. 341). It is doubtful whether more than "showings" of oil would be found west of the wells in Brea Canyon, as these holes have made a fair test of the structurally favorable land on the west end of the anticline.

The region in the vicinity of the Scarab and Union Oil Co.'s wells near the head of Brea and Alamos canyons may be considered here, as structurally the strata form the north limb of the Simi anticline. The wells already drilled have satisfactorily proved the presence of a zone of oil-bearing sands, the depth of which naturally varies with the dip and the distance north of their outcrop. (See section A–A′, Pl. XLII.) From geologic conditions existing here, oil should be found anywhere between the Union Oil Co.'s well and the Scarab wells. Drilling south of Scarab Ridge, in the N. ½ sec. 32, T. 3 N., R. 18 W., would probably be more profitable than to the north of the ridge, as the depth necessary to drill is less on the south side, and there should be no appreciable difference in production. In territory of this nature the production is generally not large, though wells may come in with a fairly good yield at first, and water is usually troublesome, as it occurs in the same sand with the oil.

LLAJAS ANTICLINE.

In lithology and structure the Llajas anticline is comparable to the Simi anticline and for this reason it may be discussed as a possible reservoir for oil.

On account of the homogeneity of the Tejon strata and the lack of distinctive beds which may be correlated or traced for any distance, it is difficult to work out the details of structure. The probable oil-bearing strata in the Llajas fold are massive brown or gray medium to fine grained sandstones containing calcareous concretions which are usually fossiliferous. These beds are compressed into a symmetrical fold whose dips range from about 10° in Aliso Canyon to 40° in and west of Llajas Canyon. Like the other folds of this region, the Llajas anticline plunges to the west, the amount of inclination being about 10° to 15°, though it may become slightly greater near Llajas Canyon. The Tejon formation is known to be oil bearing, as the productive sands of the Tapo field are in this formation. The assumption that they are oil bearing in the Llajas anticline also is strengthened by the occurrence of oil seeps in Llajas Canyon and indications of oil in Aliso Canyon. As to the source of the oil, the Tejon and Martinez shale and sandstone, in part of organic origin, evidently underlie the exposed strata in this region; and the extensive area to the east, overlain by Miocene and Pliocene formations, is capable of serving as a basin from which the oil could migrate upward and as a reservoir for accumulation along the axis of this anticline.

Some faulting which has occurred in the vicinity of the fold must be taken into account. (See sections C–C′ and D–D′, Pl. XLII.) The Santa Susana fault is the largest in this district, but it probably does not dislocate the Eocene oil-bearing strata, as its gently dipping fault plane (see section D–D′, Pl. XLII) does not extend far enough underground to reach these beds, at least in this vicinity. The fault shown on the map cutting the Tejon and later formations to the south is small and does not extend far enough west to affect any accumulation of oil. Another small fault occurs east of Dry Canyon and is probably the most serious one in this region, as it truncates the axis of the anticline. Still, the amount of displacement on this fault, which is of post-Fernando age, is not great, and it is thought that the accumulation of petroleum would not be influenced materially by it.

The most favorable place to drill to test this territory, in the writer's estimation, is along the axis of this anticline west of Llajas Creek, in sec. 22, T. 3 N., R. 17 W. A comparatively shallow hole not more than 2,000 feet deep would thoroughly test this anticline. The anticline in Browns Canyon, which probably is a continuation of the Llajas fold, is small and appears to have been fairly well tested by the wells drilled by the Placerita Oil Co.

HAPPY CAMP ANTICLINE.

Along the top of the ridge south of Happy Camp Canyon there is a very shallow syncline and immediately north of it a markedly asymmetric anticline, which appears at first sight to be a monoclinal fold. (See section A–A′, Pl. XLII.) These folds extend from the NE. ¼ sec. 21, T. 3 N., R. 18 W., westward along the top of the ridge beyond the edge of the area mapped. This anticline would serve as an excellent reservoir for petroleum, but the oil-bearing formations of this region are too far below the surface to warrant drilling.

The uppermost formation involved in this fold is the lower shale of the Modelo formation, here diatomaceous and of the type commonly associated with the oil strata north of the Santa Susana Mountains and at many other places in California. However, it is not more than 300 feet thick on the top of the anticline, and as no oil seeps are present in this vicinity nor is there any sand in or above it to act as a reservoir for the oil, this formation does not contribute to the oil possibilities of this fold. The underlying formation is the Vaqueros sandstone of the Monterey group, which is composed mainly of sandstone and conglomerate. This formation is not known to be oil bearing in this region and no evidences of oil were seen in any of its outcrops. The Sespe formation, lying below the Vaqueros, is oil bearing in its lower part, and the nearest wells drilled in this formation are at the Scarab lease, 2 miles south of this anticline. The oil-bearing strata in these wells are more than 1,300 feet below the surface, or about 3,600 feet below the base of the Vaqueros, which is about 1,800 feet thick on this ridge. As it would be necessary to drill down more than 5,000 feet to reach the oil sands, the area along this anticline does not appear to offer conditions at present favorable to prospecting for oil.

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