GEOLOGY AND OIL PROSPECTS IN WALTHAM, PRIEST, BITTERWATER, AND PEACHTREE VALLEYS, CALIFORNIA.

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INTRODUCTION.

In the investigation of the California oil fields made by the United States Geological Survey during the last 14 years the areas outside of the productive fields have received special attention, with the view to aiding the prospector by determining, so far as may be possible from a study of the surface alone, the areas in which oil would be most likely to occur. One of the regions in which it seemed that such investigation would be best repaid is the foothill belt on the west side of San Joaquin Valley near the Coalinga oil field. The Coalinga field, although one of the most productive in California, occupies a relatively small part of this foothill belt, and to casual observers there seems to be no good reason why oil should not be found in other parts of the foothill region and even in the mountainous region farther west, which is underlain in part by many of the formations that underlie the productive Coalinga field. In order to estimate the probable value of the foothills as oil-producing territory, the areas both north[1] and south[2] of Coalinga along the border of the valley were examined, and the conclusions reached are given in reports already published. The mountainous region farther west, which seemed less promising, has until recently received scant attention, but during part of the summer and fall of 1913 an area extending from the western border of the Coalinga field across the Diablo Range to the low foothills on the east side of Salinas Valley was examined. The present report gives the results obtained in this examination. The immediate reason for the investigation was the need of geologic data for the classification

[1] Anderson, Robert, Preliminary report on the geology and oil prospects of the Cantua-Panoche region, California: U. S. Geol. Survey Bull. 431, pp. 58–87, 1911. Anderson, Robert, and Pack, R. W., Geology and oil resources of the western border of the San Joaquin Valley, Cal.: U. S. Geol. Survey Bull. 603 (in preparation).

[2] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, California: U. S. Geol. Survey Bull. 398, 1910.

of the public land in the area that had been withdrawn from all forms of entry because of its possible value as oil land. As a result of the examination large areas of unappropriated public land have been restored to entry.

The chief conclusion reached regarding the occurrence of oil is that most of the region shown on the map does not offer reasonable promise of yielding petroleum and that much of it is certainly barren of oil. In general, the conditions that make it impossible to consider a large part of the region a prospective oil field are the lack of a sufficient amount of material that might reasonably be considered an original source of petroleum and the absence of a structure which would aid in the concentration of such petroleum as may occur in minute quantities throughout the rocks. In much of the region the Franciscan formation, of probable Jurassic age, which lies stratigraphically below any known oil-bearing beds in the Coast Ranges, either appears at the surface or is overlain by only a thin veneer of Tertiary rocks. Moreover, where Tertiary rocks occur they are usually closely folded and faulted and do not offer the same opportunity for the accumulation of oil as the broadly folded strata along the foothills. In parts of the region oil sands evidently occur beneath the surface, but in no part does it seem probable that any very extensive oil field awaits development. The most promising areas, which lie mainly along the western boundary of the region shown on the map, and also other areas in which the possibility that oil occurs is more slight are discussed under the heading "Local areas" (pp. 139–152).

The geology of the region is described briefly, stress being laid chiefly upon features that are believed to have some bearing on the occurrence of petroleum. Of necessity, therefore, it is impossible to discuss here many interesting geologic features that were brought out in the course of the work, such as the accurate correlation of the various formations with those of other regions and the intricate structure along the San Andreas fault. Moreover, in parts of the region, especially in the vicinity of the San Andreas fault, the structure is so complex and the distribution of the formations is so irregular that much of the detail brought out in the field work can not be shown, so that many generalizations have been made in depicting the areal geology on a black and white map of the scale of that accompanying this report. In order to show more clearly the relation between the geology in parts of this region and that about Coalinga, the areal geology of a small portion of the district described in the Coalinga report[1] is reproduced on the map (Pl. V).

[1] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, California: U. S. Geol. Survey Bull. 398, 1910.

ACKNOWLEDGMENTS.

J. D. Northrop was a member of the field party during the later part of the season, and many of the facts here recorded are taken from his notes.

The writers take pleasure in acknowledging their grateful appreciation of the courtesies extended to them by the officers of the oil companies in furnishing data regarding the wells and by the inhabitants of the region on whose hospitality they had largely to depend in the study of a region so sparsely settled. Special acknowledgment is due to E. A. Starke, of the Standard Oil Co., and to G. C. Gester, geologist for the Kern Trading & Oil Co.

Before this investigation was undertaken very little work had been done on the geology of the area, almost the only published accounts dealing with it being the brief note by Eldridge on the asphalt deposit near Lonoak[1] and incidental mention of various general features in a paper by Homer Hamlin on the water resources of Salinas Valley.[2] Besides these accounts a few unpublished notes by Eldridge and Hamlin have been available.

GEOGRAPHY.

The area studied in detail and shown on the map lies about 140 miles southeast of San Francisco and forms a strip 40 miles long and 11 to 14 miles wide, extending northwest and southeast diagonally across the Diablo Range. It includes about 500 square miles in the southern parts of Fresno and San Benito counties and in the eastern part of Monterey County. Coalinga, at the eastern end of the area, is the terminus of a branch of the valley line of the Southern Pacific Co. From Coalinga one of the main wagon roads through the Diablo Range leads up Waltham Valley to Priest Valley and thence down the valleys of Lewis and San Lorenzo creeks to King City, in Salinas Valley. A branch road leaving the main road above Alcalde Canyon leads south across Jacalitos Creek to Parkfield, and other branch roads pass through Peachtree Valley to the Stone Canyon coal mine and up Bitterwater Valley to the valley of San Benito River. A 6-inch pipe line, owned by the Associated Oil & Transportation Co., passes through Waltham, Priest, Lewis Creek, and Bitterwater valleys, and through it oil is pumped from Coalinga to Monterey.

The eastern edge of this belt includes Pleasant Valley, which lies in the foothills that border San Joaquin Valley, at an elevation of about 650 feet above the sea. The southwestern part of the area mapped includes the low hills that border Salinas Valley, which has

[1] Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 1, pp. 407–410, 1901.

[2] Hamlin, Homer, Water resources of Salinas Valley, Cal.: U. S. Geol. Survey Water-Supply Paper 89, 91 pp., 12 pls., 1904.

an elevation of about 400 feet and lies 6 to 10 miles to the southwest. Between these two foothill belts the mountainous part of the Diablo Range rises gradually to altitudes of over 4,000 feet. The culminating points in this part of the range are Hepsedam, which stands 4,496 feet above the sea; Center Peak, 4,539 feet; and Smith Mountain, 3,967 feet.

Here as elsewhere the range is an almost perfect reflection of the structure. It is not composed of a single ridge but of a number of somewhat broken parallel ridges that separate relatively narrow valleys. These ridges trend obliquely to the course of the main range and are determined by pronounced folds or faults. Parts of two such ridges lie in the area shown on the map. One extends from Smith Mountain northwestward to and beyond Charley Mountain and separates Waltham and Priest valleys from Peachtree Valley and Slack Canyon. The other extends from Sherman Peak through Center Peak to a point north of Hepsedam and separates Bitterwater, Priest, and Waltham valleys from the drainage basins of Los Gatos Creek and San Benito River. The divide which separates the waters that drain into Salinas Valley from those that empty into San Joaquin Valley and which may therefore be considered the crest of the Diablo Range cuts directly across these ridges. Priest and Charley valleys are two small faulted synclinal valleys that lie practically at the crest of the range. Both lie in the Salinas drainage basin, but both are being rapidly cut away by streams of high gradient that drain eastward into San Joaquin Valley.

The climate is dry and hot in summer, particularly on the eastern slope of the range. A few of the larger streams carry water throughout the year, but most of them are intermittent, and nearly all the water contains sufficient salts to make it unpalatable. A few of the springs, however, particularly those in the Franciscan formation and in the coarse conglomerate of the Cretaceous, furnish excellent water. In order to obtain boiler water for the pumping stations along the pipe line of the Associated Oil & Transportation Co., several of the better springs have been developed and the water piped for many miles. The main supply comes from a number of springs near Hepsedam which furnish the water for two stations on Lewis Creek and one at the head of Bitterwater Valley.

The plains and lower hills are bare except for a sparse growth of sagebrush and short grass. The mountainous part is more or less covered by chaparral, but the growth is rarely thick enough to be impassable. A light growth of small pine and manzanita is common on the outcrops of diatomaceous shale, and oaks are scattered throughout the region.

The amount of level ground suitable for agriculture is small, and the country is used generally as a cattle range, for despite the dry climate there is a good growth of grass in wet seasons. In Bitterwater, Priest, and Peachtree valleys and in some of the small valleys tributary to Salinas Valley several thousand acres are dry farmed; and on San Lorenzo Creek, both near Lonoak and just west of the area shown on the map, small areas of alfalfa are under irrigation.

GEOLOGY.

DISTRIBUTION AND GENERAL RELATIONS OF THE ROCKS.

The area shown on the map (Pl. V), forming a narrow belt that extends across the Diablo Range, does not present a single type of structure but is divided by the San Andreas fault into two parts, which are so distinct, both structurally and stratigraphically, that they may almost be regarded as distinct geologic provinces. The difference in the stratigraphic section exposed in the two parts of the region may be seen by comparing the two columnar sections (figs. 3 and 4). Southwest of the fault are the foothills that border Salinas Valley, and northeast of it is the main Diablo Range. This range may also be considered as composed of two parts—the central mountain mass, an area of many short irregular folds and faults, and the eastern foothills, an area in which the rocks are flexed into a few broad folds. This separation is indefinite, however, as the structure becomes gradually more complex westward from the edge of San Joaquin Valley toward the mountains, and a sharp line of division, such as that of the San Andreas fault, is nowhere apparent.

On the southwest side of this fault much or probably all of the region is underlain at no great depth by granitic rocks. These rocks are exposed only in small areas in the northwest corner of the region mapped, but farther north they appear at the surface for about 40 miles and form the Gabilan Range. Resting upon the eroded surface of this granitic mass are late Tertiary sand, clay, and diatomaceous shale. These beds, although tilted to low angles whose direction of dip is somewhat irregular, disclose few well-marked folds. The lower part of these late Tertiary beds is believed to be the equivalent of the Santa Margarita formation (middle Miocene), which is typically developed in the upper end of Salinas Valley, some 40 miles to the south. Their upper part, represented mainly by relatively thin deposits of gravel and clay on the flat-topped ridges, is correlated with the Tulare formation (Pliocene).

Northeast of the San Andreas fault granite does not appear, and the oldest rocks are those of the Franciscan formation (Jurassic?). As mapped, this formation comprises a rather heterogeneous mass of more or less altered sedimentary rocks and various igneous rocks that are intruded into them. Strictly speaking the igneous rocks are not a part of the Franciscan, but for convenience in the present discussion

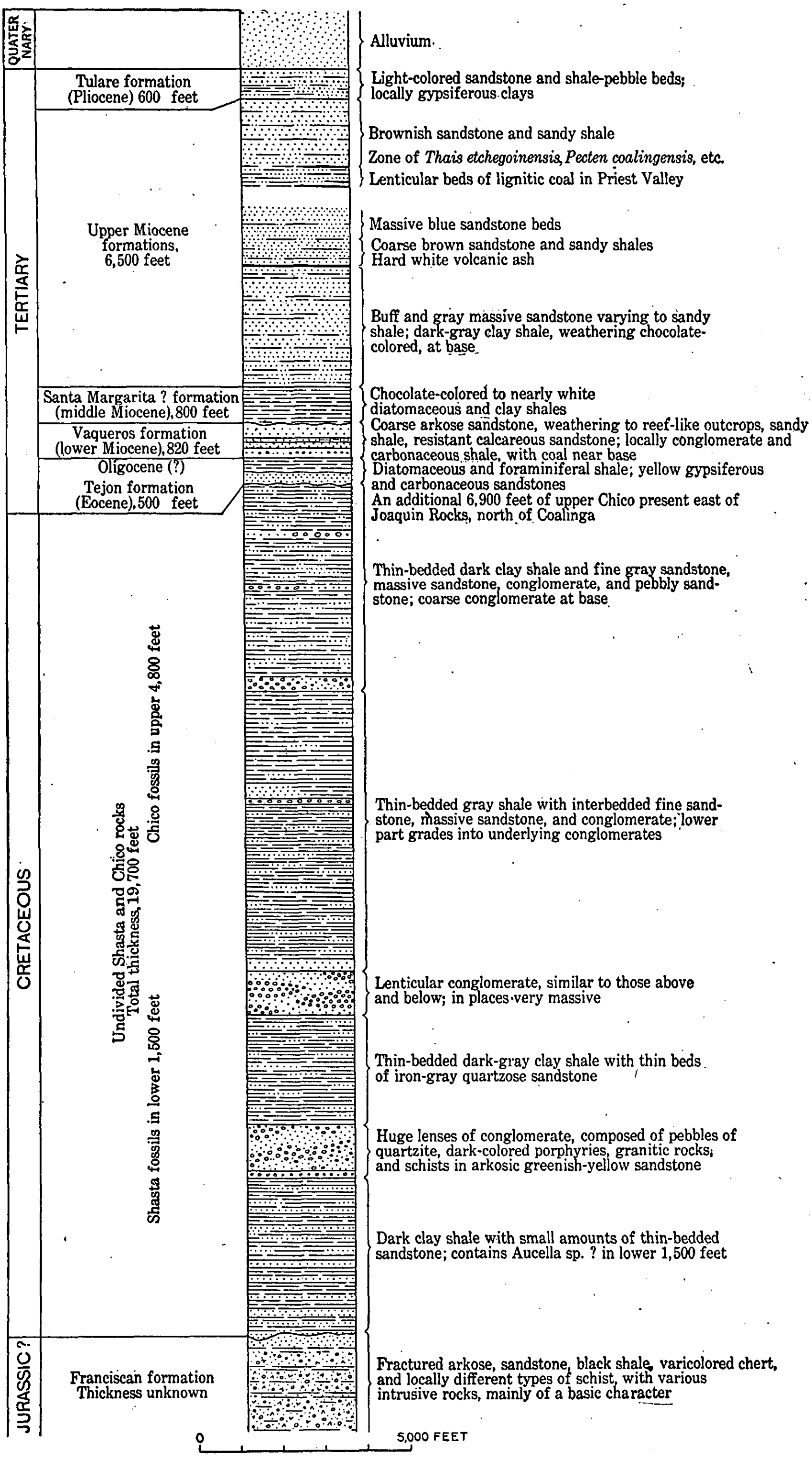


FIGURE 3.—Columnar section of rocks northeast of the San Andreas fault, central California.

the two are represented on the map and discussed together. Resting unconformably upon the Franciscan formation are dark clay shale, sandstone, and coarse conglomerate which represent both Lower and Upper Cretaceous. Eocene and Oligocene rocks are absent west of the Coalinga district, and the Vaqueros formation (lower Miocene) rests upon the Cretaceous or older rocks with marked unconformity. The Vaqueros formation is in turn overlain unconformably by a body of diatomaceous shale, whose equivalent was termed the Santa Margarita (?) formation[1] in the Coalinga report. For convenience, and also to show its equivalence to the shale in the region south of Coalinga, the same name is used here. The later Tertiary rocks, which overlie the Santa Margarita (?) formation with probable unconformity, comprise a great mass of clay shale, brownish and bluish sandstone, and conglomerate. The lower part of this series of beds is the equivalent of the Jacalitos and Etchegoin formations, which

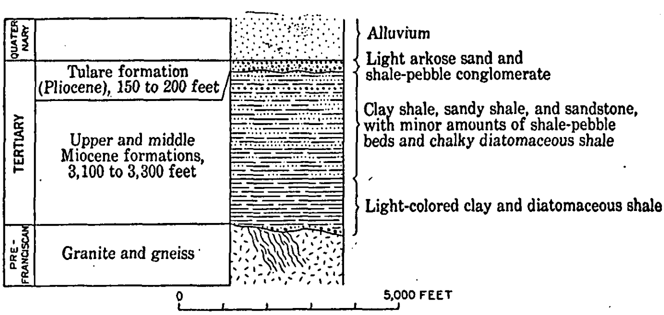


FIGURE 4.—Columnar section of rocks southwest of the San Andreas fault, central California.

occur along the foothills near Coalinga; the upper part, which is distinguished from the lower by its abundant pebbles of diatomaceous shale, is the equivalent of the Tulare formation (Pliocene) of the Coalinga district and the area farther east.

In mapping the area between the San Andreas fault and the Coalinga district the formations younger than the Vaqueros and older than the Tulare were grouped into two divisions. The lower division embraces the diatomaceous shale that was described in the Coalinga report as the Santa Margarita (?) formation; and the upper division, which is termed the upper Miocene, comprises the Jacalitos and Etchegoin formations. The grouping of the formations into these map units has been adopted in order that the areal distribution of the diatomaceous shale might be shown, as it has a bearing on the possible occurrence of oil.

In the area west of the San Andreas fault the diatomaceous shale is so irregularly distributed that no attempt has been made to show it

[1] U. S. Geol. Survey Bull. 398, p. 88, 1910.

separately on the map. It has therefore been grouped with the overlying fossiliferous sands, which are regarded as the equivalent of the typical Santa Margarita and which are shown on the map as part of the upper Miocene.

GRANITIC ROCKS.

Granitic and associated schistose rocks are exposed in the western part of the region in small areas from which the overlying Tertiary beds have been eroded and along the San Andreas fault zone, where a small block of granite is faulted up against the late Tertiary. These rocks form part of a mass upon which the Tertiary beds rest in much or possibly all of the Salinas Valley. Granite rocks, evidently part of this same mass, outcrop in extensive areas in the Gabilan Range, whose south end lies about 10 miles west of Bitterwater Valley, and also in the Santa Lucia Range, on the west side of Salinas Valley. The granitic and associated schistose rocks in the Santa Lucia Range have been termed by Willis[1] the Coast complex. The age of the granite is not definitely known, but many geologists who have worked in the Coast Ranges believe that it is the equivalent of the granite in the Sierra Nevada and it is presumably of Jurassic age. In the area mapped the granite is in contact only with late Tertiary sedimentary beds which have been deposited upon it.

JURASSIC (?) SYSTEM.

FRANCISCAN FORMATION.

The oldest sedimentary rocks in this part of the Diablo Range are those which occur in irregular areas in the central part of the range and which are mapped as the Franciscan formation. These rocks are of a variety of lithologic types, ranging from relatively little altered arkosic sandstone and shale to different kinds of schist, of which bluish glaucophane schist is prominent. Probably the type of rock that appears most abundantly is a very arkosic sandstone, much fractured and seamed with calcite. Small masses of gray limestone occur sparingly, but thin-bedded reddish and greenish chert is abundant and weathers characteristically to prominent ragged outcrops. These sedimentary rocks are intruded by various igneous rocks, mainly of rather basic character, which are largely altered to serpentine, although locally the intrusive rocks are fairly fresh and unaltered. The relatively unaltered character of the rocks is particularly noticeable near Hepsedam, where there is a considerable area of rather coarse textured, little altered granitoid rock, composed predominantly of hornblende and feldspar. The intrusive rocks, although clearly younger than the sedimentary beds and not a

[1] Willis, Bailey, Geol. Soc. America Bull., vol. 11, p. 419, 1900.

part of the Franciscan, have been grouped with them in the mapping as the Franciscan formation.

The granitic rocks and the Franciscan formation are nowhere in contact in this region and definite evidence regarding their relations can not be offered. However, Fairbanks[1] has described the Franciscan rocks as resting unconformably upon the eroded surface of the "Coast complex" at Slates Springs, on the west side of the Santa Lucia Range. As the various exposures of granite appearing about Salinas Valley are believed to be parts of one mass, the Franciscan rocks in the Diablo Range must be considered younger than the granite exposed west of the San Andreas fault. The Lower Cretaceous (Shasta series) is evidently unconformable upon the Franciscan. It shows fewer fractures and none of the results of metamorphism which the Franciscan rocks exhibit, and in most of the region it may be differentiated readily from the older rocks. Along the San Andreas fault zone, however, the two formations are so fractured and intermingled that in the absence of fossils in the younger they appear to be indistinguishable.

CRETACEOUS SYSTEM.

Overlying the Franciscan formation unconformably is a succession of beds of dark clay shale, arkosic sandstone, and conglomerate, which, in the area mapped, have an aggregate thickness of over 19,000 feet. This succession of strata embraces both the Shasta series (Lower Cretaceous) and the Chico formation (Upper Cretaceous). Farther north, along the east flank of the Diablo Range, about 12 miles north of Coalinga, Cretaceous beds having a total thickness of at least 6,900 feet overlie the youngest Cretaceous beds exposed in the area shown on Plate V, giving a thickness of approximately 25,900 feet for the Cretaceous section in the southern part of the Diablo Range. In many places the Cretaceous beds, especially those belonging to the Shasta series, resemble somewhat the sedimentary beds in the Franciscan formation. The two terranes are evidently unconformable, however, for the Franciscan is much folded, faulted, and locally metamorphosed and is intruded by a multitude of igneous rocks, whereas even the lowest beds of the Shasta are much less fractured, are unmetamorphosed, and in this region are intruded by few if any igneous rocks. The unconformity between the youngest Cretaceous formation in this region and the oldest Tertiary in contact with it is clearly shown by the absence of many thousand feet of beds in the Upper Cretaceous and early Tertiary which are exposed in hills north of Coalinga.

[1] Fairbanks, H. W., Stratigraphy at Slates Springs: Am. Geologist, vol. 18, pp. 350–353, 1894.

The Cretaceous section is best developed on the north side of Waltham Valley, where alternating beds of clay shale, arkosic sandstone, and conglomerate of variable thickness form a northward-dipping monocline. In the report on the geology of the Coalinga district the Cretaceous rocks were described as embracing three divisions, an upper, middle, and lower, the last two of which are well developed in the region described in the present report. (See Pl. V.) The line of separation between these two is the base of a massive conglomerate which outcrops near the crest of Juniper Ridge. The lower division, which is exposed southwest of that ridge, is about 14,900 feet thick. Although the lithologic changes in most of this division are so numerous both vertically and along the strike that it is difficult to separate it into well-defined members, it may for convenience be described as being composed of two parts. The lower part embraces about 3,500 feet of a dark-gray clay shale that weathers to light greenish gray, interstratified with sandy shale and numerous thin beds of fine-grained iron-gray quartzitic sandstone. This part is best exposed southwest of Center Peak, where it rests, apparently in unfaulted contact, upon the Franciscan.[1] The upper part comprises about 11,400 feet of interstratified clay shale like that in the lower part, sandy shale, massive sandstone, and conglomerate. The conglomerate, whose presence distinguishes the upper from the lower part of the division, is lenticular, in places reaching a thickness of about 1,200 feet and in places thinning and grading laterally into sandstone. The pebbles are well rounded and the largest measure about 8 inches in diameter. They are composed of quartzite, dark-colored porphyritic rock, and granitic rock and are embedded in a matrix of dark-greenish sandstone that weathers reddish brown. Between Waltham Valley and Los Gatos Creek the upper part of the lower division contains two prominent lenses of conglomerate. The lower lens, which has a maximum thickness of about 1,200 feet, forms the crest of Center Peak, from which it extends southeastward as a prominent ridge that trends nearly parallel to Juniper Ridge, on the west side of the canyon in which Fresno Hot Springs is situated. About 2,500 feet above this conglomerate and separated from it by interstratified clay shale and sandstone is another lens of coarse material which forms the ridge east of Fresno Hot Springs. Between this conglomerate and that which forms the base of the middle division are sandy shale and sandstone.

The middle division includes the conglomerate exposed along Juniper Ridge and a succession of clay shales and sandy shales that

[1] Owing to errors in the preparation of the map the Franciscan rocks in this area are shown as the Santa Margarita (?) formatiton, and in the geologic section on the map the two parts of the lower division of the Cretaceous system are termed the lower and middle divisions, and the middle division is termed the upper division.

overlie it. In the report on the Coalinga district[1] the thickness of this division exposed on Alcalde Creek is given as 4,800 feet. This division of the Cretaceous is exposed also north of Coalinga, where, on the east flank of the Coalinga anticline northeast of the Joaquin Rocks, it is overlain by about 5,300 feet of massive concretionary sandstone and dark clay shale, upon which rest about 1,600 feet of shale filled with the remains of diatoms and foraminifers. These two last-mentioned members constitute what was described in the Coalinga report as the "upper member of the Knoxville-Chico rocks."

About 1,500 feet above the base of the lower division were found abundant specimens of *Aucella crassicollis* (?), a fossil typical of the Lower Cretaceous. As there appears to be no marked lithologic or stratigraphic break in the lower 3,500 feet of the Cretaceous section—that is, up to the conglomerate that separates the two parts of the lower division—it seems probable that all of this part of the lower division is of Lower Cretaceous age. Upper Cretaceous fossils have been found in the middle of the three divisions northeast of Juniper Ridge, and the conglomerate at the base of that division was described in the Coalinga report as the probable base of the Upper Cretaceous. Only two fossils have yet been found in the upper part of the lower division. These, which were found near the top of the conglomerate that separates the two parts of the lower division, although not diagnostic, suggest Upper Cretaceous rather than Lower Cretaceous age, so that the line between the Shasta and Chico may occur at the base of the conglomerate that extends southeastward from Center Peak, instead of at the base of the conglomerate that appears at the base of the upper division along Juniper Ridge, as was suggested in the report on the Coalinga district.[1]

The Cretaceous near Jacalitos Creek and along the San Andreas fault zone consists largely of dark clay shale of Lower Cretaceous age, in which *Aucella crassicollis* (?) is fairly abundant. Only a few of the areas of Cretaceous that occur along the south side of Waltham and Lewis creeks have been shown, many small areas having been grouped in the mapping with the Franciscan.

Upper Cretaceous rocks are unknown south of Waltham Valley within the boundary of the area shown on Plate V. Rocks of that age occur, however, in a small area at the crest of the Diablo Range about a mile north of the Stone Canyon coal mine.

TERTIARY SYSTEM.

EOCENE AND OLIGOCENE (?) SERIES.

Early Tertiary rocks are but sparingly represented in the area mapped, outcropping only in a narrow belt some 3 miles in length

[1] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district: U. S. Geol. Survey Bull. 398, p. 53, 1910.

in the foothills west of Coalinga. Near the San Joaquin Valley coal mine these beds, which were mapped as the Tejon formation in the report on the Coalinga district[1] but which include probable Oligocene as well as true Tejon, rest unconformably upon the Cretaceous and are overlain unconformably by the Vaqueros formation. The beds consist of about 200 feet of whitish gypsiferous and carbonaceous Eocene sandstone (the true Tejon) overlain by white diatomaceous and foraminiferal shale of probable Oligocene age. These beds outcrop for many miles to the north in the foothills bordering San Joaquin Valley, where the shale is at least 1,000 feet thick. They also continue to the south, probably underlying much of the area where late Tertiary rocks appear at the surface south of Coalinga, and outcrop along the flank of Reef Ridge, southeast of the area shown on the map (Pl. V). The Oligocene (?) diatomaceous shale overlying the Tejon formation (Eocene) is of economic importance, as it is probably the ultimate source of most of the petroleum in the Coalinga field.

MIOCENE SERIES.

VAQUEROS FORMATION (LOWER MIOCENE).

The oldest Tertiary formation that has any considerable areal distribution in the region mapped is the Vaqueros formation, which is composed mainly of massive sandstone that contains a good marine fauna of lower Miocene age. It outcrops in the foothills west of Coalinga; in irregular areas in the mountainous part of the range, mainly south of Waltham and Priest valleys; and in a narrow belt, about a mile in length, northeast of Priest Valley. It doubtless occurs also beneath the later Tertiary formations in parts of Waltham and Priest valleys, but its extent there is a matter of conjecture. Lower Miocene rocks do not outcrop west of the San Andreas fault within the area shown on Plate V. The Vaqueros occurs, however, in a narrow fault block within the San Andreas fault zone southwest of the Stone Canyon mine, and farther southeast in the Parkfield region it is reported by Eldridge[2] on the southwest side of the fault zone.

In the foothills west of Coalinga this formation overlaps unconformably the Oligocene (?) diatomaceous shale, and elsewhere in the area mapped it rests with marked unconformity upon either the Franciscan or the Cretaceous rocks. Resting unconformably upon the Vaqueros is a body of diatomaceous shale that is mapped as the Santa Margarita (?) formation. The unconformity between these formations is well shown in the central part of the range by the irregular way in which the Santa Margarita (?) overlaps the Va-

[1] U. S. Geol. Survey Bull. 398, pp. 62–75, 1910.
[2] Eldridge, G. H., unpublished notes.

queros. The relationship is most clearly shown on the west side of Deep Well Canyon, where the two formations show a discordance in dip of over 20° and the basal sandstone of the Santa Margarita (?) lies on the eroded edges of the Vaqueros. The unconformity is also indicated in the syncline north of Smith Mountain, where the line along which the Vaqueros is folded is offset from that along which the Santa Margarita (?) is folded.

Neither the lithology nor the thickness of the Vaqueros is constant, and although the variation in thickness is partly due to erosion subsequent to deposition and the removal of the upper part of the formation, it is also partly due to the fact that the formation was laid down upon a very irregular surface and that in consequence the lowest beds were not everywhere deposited.

The Vaqueros is probably most completely exposed near the crest of the range southeast of Smith Mountain, where it has a thickness of about 820 feet. The lower 200 feet or so is composed of carbonaceous shale, containing beds of coal and a conglomerate and coarse sandstone, made up largely of fragments of Franciscan rocks. Above this is about 220 feet of very resistant calcareous sandstone that forms the crest of the castellated ridge of which Smith Mountain and Smith Pinnacles are parts. Overlying the calcareous sandstone and forming the upper part of the Vaqueros are about 400 feet of alternating hard and soft sandstones. The more resistant beds weather out prominently and in places where the overlying softer beds have been stripped off form broad, bare dip slopes 400 feet or more in length. The presence of such resistant reef-like beds as these is one of the most characteristic features of the Vaqueros in the southern part of the Diablo Range.

On Lewis Creek the Vaqueros contains a considerable amount of pinkish shale, probably diatomaceous, which is similar to that in the overlying Santa Margarita (?), and the two formations are separable with difficulty.

SANTA MARGARITA (?) FORMATION (MIDDLE MIOCENE).

Resting unconformably on the Vaqueros is a formation composed of 700 to 800 feet of purplish to gray diatomaceous and clay shale which weathers to pinkish-white or chocolate-colored outcrops. This formation is practically continuous in outcrop and varies little in lithology from the north side of Lewis Creek to the southeast corner of the area shown on the map and for about 25 miles farther south along Reef Ridge. In the report on the geology and oil resources of the Coalinga region this shale was described as the probable equivalent of the Santa Margarita formation. In order to show its equivalence to the shale south of Coalinga, the name Santa Margarita (?) is used in the present discussion.

Where the Santa Margarita (?) is best exposed the lower 15 to 40 feet is a massive arkosic sandstone lithologically like that in the Vaqueros formation. Above this lower sandstone is from 200 to 800 feet of hard and brittle diatomaceous clay shale which breaks with a splintery fracture and weathers pink or nearly white. The shale forms little or no soil and weathers to steep ridges and knobs which are recognizable at considerable distances by their chalky-white or pinkish color and by the light growth of pine and manzanita which they support. Toward the top the shale gradually becomes more clayey and grades into a dark-gray clay shale which weathers to platy chocolate-colored fragments and forms a clay soil. This change does not seem to take place along an exact stratigraphic line, but from place to place one facies increases in thickness at the expense of the other. No evidence of unconformity between the diatomaceous shale of the Santa Margarita (?) formation and the sandy beds of the upper Miocene was found, the line of contact being drawn at the horizon where the shale becomes sandy rather than clayey and weathers yellowish brown rather than purplish.

UPPER MIOCENE FORMATIONS.

Distribution and character.—Numerous beds of sandstone, conglomerate, and diatomaceous and clay shale that were deposited during the later part of the Miocene have been grouped together in the mapping as "chiefly upper Miocene." These beds occur on both the northeast and southwest sides of the San Andreas fault, but they are not precisely the same in character nor exactly equivalent stratigraphically in the two areas. Most if not all of the rocks thus mapped southwest of the fault are regarded as the equivalent of the Santa Margarita formation and therefore as of middle Miocene age. Those northeast of the fault constitute the westward continuation of the Jacalitos and Etchegoin formations (upper Miocene) in the Coalinga region and, in the lower part, embrace some beds of probable Santa Margarita (middle Miocene) age. The reasons for grouping the formations in this manner in the geologic mapping is explained in the general statement about the geology. (See p. 125.) The Jacalitos and Etchegoin formations are believed to be in the main younger than the true Santa Margarita, although the fauna contained in the lower part of what is mapped as upper Miocene in Waltham Canyon shows a close similarity to that of the true Santa Margarita. It should also be noted that the diatomaceous shale in the lower part of the beds mapped as upper Miocene west of the fault may be the correlative of the shale mapped as the Santa Margarita (?) formation east of the fault. A full discussion of the possible relationship of these formations can not be given here nor can a decision be reached until careful paleontologic study is made.

Area southwest of the San Andreas fault.—Between the San Andreas fault and Salinas River the granite is overlain by beds of shale and sandstone, which contain marine fossils characteristic of the Santa Margarita formation and which in the area mapped have a maximum thickness of about 3,300 feet. Near Lonoak the lower 800 to 1,000 feet is composed largely of diatomaceous and clay shale which weathers to a light-pink or chocolate color and which contains relatively little interstratified sand, although the lower part is in some places somewhat sandy and in a few places, as at the asphalt quarry west of Lonoak, is a coarse arkosic grit. This shale resembles closely the "chalky" shale of the Monterey group. It was described as Monterey shale by Eldridge,[1] but as the writers discovered in it fossils that are believed to be characteristic of the Santa Margarita formation, they have grouped it in the present report with the overlying more sandy beds. Shale of this type has a somewhat local distribution in the area mapped, apparently grading along the strike into sandy shale and sandstone. Overlying the diatomaceous shale near Lonoak is about 1,100 feet of sandy shale, above which is about 1,200 feet of sandy shale and fine-grained clayey sandstone containing thin beds of diatomaceous shale and of conglomeratic sandstone filled with pebbles of white flinty shale. The interbedded shale in the upper 1,200 feet is very light colored and "chalky" and is perhaps partly volcanic ash. Although occurring in beds only a few feet thick, interstratified with sandstone, it is almost free from coarse material. Marine fossils are abundant in the upper part of the formation, the large barnacle *Tamiosoma gregaria* being exceptionally common in the uppermost 1,000 feet.

Area northeast of the San Andreas fault.—Northeast of the San Andreas fault is a succession of beds of sandstone, sandy shale, and conglomerate, which in the hills west of Coalinga is separated into the Jacalitos and Etchegoin formations but which in the rest of the area is mapped with the upper Miocene. These beds rest upon the diatomaceous shale of the Santa Margarita (?) formation, into which they seem to grade, and the line of separation has been drawn arbitrarily so that the predominantly shaly beds are included in the Santa Margarita (?) and the predominantly sandy beds in the upper Miocene. The line between the upper Miocene and the Tulare formation (Pliocene) is only a little more definite and has been drawn at the base of the beds which contain abundant pebbles of diatomaceous shale.

In the upper part of Waltham Valley the upper Miocene beds have a maximum thickness of about 6,500 feet. The lower 500 to 600 feet is mainly sandy shale that weathers yellow or brown and shaly

[1] Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 1, p. 408, 1901.

sandstone, above which is about 2,800 feet of buff, brown, and greenish-yellow sandstone and shaly sandstone with a little coarse grit and conglomerate. Thin beds of white ash occur at irregular intervals in the upper 1,000 feet of this member, the most prominent being a bed 10 to 20 feet thick that occurs about 2,700 feet above the top of the Santa Margarita (?) formation. The buff sandstone grades upward into beds, less than 600 feet thick, of massive coarse-grained white and blue sandstone interbedded with fine sandstone. Above the blue sandstone is about 900 feet of brown sandstone and sandy and carbonaceous shales. In Priest Valley the upper 425 feet of this member contains lignitic sandy brown shale, in which occur beds of low-grade coal that have been prospected at a few places. Above the carbonaceous beds massive gray and buff sandstone and clayey sands alternate for 1,500 feet up to the beds containing shale pebbles, which form the base of the Tulare.

TULARE FORMATION (PLIOCENE).

The youngest formation in this region that has suffered marked deformation is composed of beds of rather poorly consolidated sandstone, shale, and conglomerate, which were deposited either in lakes or subaerially. On account of similarity in lithologic character and in stratigraphic position this formation is correlated with the Tulare formation, which is typically exposed in the Coalinga region. In at least part of the Priest Valley region it lies unconformably upon the underlying upper Miocene formations just described, and throughout the region it is overlain with marked unconformity by the flat-lying Quaternary deposits. Beds correlated with the Tulare are exposed in three general areas—(1) in the Priest Valley syncline, (2) along the San Andreas fault zone, and (3) on the foothills west of Peachtree Valley, in the center of the Peachtree syncline, and northwest of the area mapped.

In the southern part of Salinas Valley is the Paso Robles formation, which consists in part of fresh-water beds similar in lithologic character to the Tulare and probably of the same age, but work done near the type locality by Robert Anderson indicates that there is a lower marine member of the Paso Robles, which is the representative of the Etchegoin formation of the Coalinga region, and for this reason the name Tulare is used for the purely fresh-water beds of the Priest Valley and neighboring regions.

The lithology and thickness of the Tulare varies considerably in the different areas. In the Priest Valley syncline it comprises not less than 500 to 600 feet of incoherent light-colored, poorly sorted angular, distinctly arkosic sandstone and conglomerate. Pebbles of diatomaceous shale like that in the Santa Margarita (?) formation northeast of the San Andreas fault and in the Monterey group west of the Salinas Valley are very common in the conglomerate. These beds weather to light-gray outcrops that contrast markedly with the brownish color that is characteristic of the upper Miocene. There is no sharp change in lithology between the upper Miocene and the Tulare, and the line of contact has been drawn at the base of the beds which contain abundant pebbles of diatomaceous shale. This gradual change in lithology and the lack of any structural evidence of interrupted sedimentation suggest that the formations are conformable here. Also in much of Waltham and Priest valleys a fossiliferous zone containing characteristically *Pecten coalingensis*, *Pecten wattsi*, and *Thais etchegoinensis* occurs at about the same stratigraphic distance below the base of the Tulare, suggesting that an unconformity, if present, does not represent an important interval of erosion.

In the San Andreas fault zone the Tulare formation is composed of coarse arkose and shale pebble beds like those described above and in addition contains red and green clays, in which there are numerous beds of gypsum. The unconformity between the Tulare and the upper Miocene formations is shown by the presence of a conglomerate near Alvarez Creek containing numerous bowlders of fossiliferous sandstone of upper Miocene age, the equivalent of the Jacalitos or Etchegoin formation. Southwest of the San Andreas fault the Tulare comprises a basal bed some 10 to 15 feet thick of indurated shale-pebble conglomerate, above which are incoherent gray sand and sandy clay, the total thickness being not over 150 or 200 feet.

QUATERNARY SYSTEM.

In Quaternary time the Priest Valley region was an area of erosion rather than of deposition, and it therefore contains no large Quaternary deposits. The beds of the larger streams are covered with alluvium, but this material is only a temporary deposit, formed in the course of its transportation beyond the area here described. Southwest of the San Andreas fault alluvium seems to be collecting in the stream beds, and the alluvial deposits on the valley floors are relatively greater in that area than in the area northeast of the fault.

STRUCTURE.

The dominant structural feature in this part of the Diablo Range is the San Andreas fault, which trends diagonally across the region mapped, separating it into two parts, which exhibit two distinct types of structure. The dissimilarity in the stratigraphic record on opposite sides of the fault, or fault zone, as it might more properly be termed, shows that pronounced movements have taken place along it since at least as far back as middle Miocene time. The movements along the line farther north, which caused the earthquake of April 18, 1906, were almost wholly horizontal, but the lack of the Franciscan, the Cretaceous, and the Vaqueros formation and the presence of granite at or close to the surface in the area west of the fault seem to indicate that there was once very considerable vertical movement along this general zone, the net result of which was an elevation of the mass lying west of the fault relative to that lying east of it. The fault zone varies in width from half a mile to a mile and is composed of a number of approximately parallel fractures, which separate long blocks of the various formations. The line shown on the map as the San Andreas fault is the fracture along which movement seems to have taken place most recently and which may be considered the active fault. This line is marked by numerous small sunken areas, some of which are occupied by lakes throughout the year and which are especially notable along the flat summit of Mustang Ridge.

In the area west of the fault the granite has evidently furnished a foundation sufficiently rigid to prevent more than a minor amount of warping, and the Tertiary beds a short distance west of the fault zone are rarely tilted over 10° and in most places less than 5°, forming short and for the most part irregular folds or domes. The only large fold in this part of the region is the broad, shallow Peachtree syncline, which extends northwestward from a point near the center of the Peachtree ranch for more than 10 miles beyond the boundary of the area shown on the map. The dips on either flank of this fold are so low through most of its course that the precise location of its axis is hard to determine. The dip on both flanks is slightly irregular, and at one place in Bitterwater Valley, just below the mouth of Lewis Creek, a low dip toward the east forms a very short subsidiary anticline in the east flank of the larger syncline.

In the mountainous part of the range northeast of the fault zone the rocks are bent into a multitude of folds and are broken by faults, most of which trend approximately parallel to the San Andreas fault and somewhat obliquely to the course of the Diablo Range. The largest of these folds is the syncline which forms Priest Valley and which extends from it southeastward through the upper part of Waltham Valley. This general synclinal structure continues, although not exactly as an unbroken syncline, farther southeastward past Curry Mountain and merges into the monoclinal structure along the flank of Reef Ridge. In this structural trough Tertiary beds which aggregate in thickness about 8,500 feet have been infolded. On the south the basin is bounded by the mass of Franciscan rocks that, with various infolded and faulted bodies of Cretaceous and Tertiary rocks, forms the ridge on the south side of Waltham and Priest valleys. On the north side of the basin the Tertiary formations abut against the northward-dipping monocline of Cretaceous rocks. Although the folding is pronounced and the Tertiary beds are in places tilted on edge or are even overturned, yet the forces causing the deformation seem to have spent themselves in a relatively narrow zone and did not greatly affect the Cretaceous beds that lie 1½ to 2 miles from the axis of folding. These Cretaceous beds were evidently tilted before middle Miocene time to approximately their present attitude, as is shown by the fact that in small areas north of Priest Valley and near Alcalde Canyon almost flat Tertiary beds rest upon the steeply dipping Cretaceous rocks. The difference in the character of the foundation upon which the upper Miocene formations rest in the north and south sides of Waltham and Priest valleys suggests that the fold in the Tertiary beds follows an old line of weakness along which the Cretaceous beds were faulted against the Franciscan in pre-middle Miocene time. Between the center of the synclinal basin and the San Andreas fault are numerous areas of Tertiary rocks flexed into short, shallow folds. The synclines are for the most part unbroken, but the anticlines are almost invariably faulted and a narrow belt of Franciscan rocks is exposed.

The complexity of the structure gradually diminishes toward the east, and in the foothills bordering the San Joaquin Valley the Tertiary rocks which appear at the surface form only a few broad folds. In the area shown on the map only the part lying east of Curry Mountain may be said to belong to this foothill belt.

PETROLEUM.

CONDITIONS IN THE COALINGA DISTRICT.

The area discussed in this report lies mainly in the mountainous region west of the Coalinga oil field, one of the largest producing fields in California, and a discussion of the possibility of developing oil in it may well be preceded by a brief account of the occurrence of oil in the productive field.[1]

The oil sands in the Coalinga district lie in the midst of a thick mass of sedimentary beds, mainly of marine origin and of Cretaceous and Tertiary age. These beds are mostly sandstone and clay or clay shale, but they include two persistent formations which are filled with the remains of minute organisms—diatoms and foraminifers—and which are commonly termed diatomaceous shales. One of these formations lies at the top of the Cretaceous and the other in the lower part of the Tertiary, and in much of the region the two are separated by many hundred feet of sandstone and shale. With one exception the oil-bearing sands may be grouped in two

[1] For a full discussion of the Coalinga district see U. S. Geol. Survey Bull. 398, 1910.

zones, one including the sandy beds immediately overlying, underlying, and intercalated with the lower (Cretaceous) shale, the other comprising the sands that have a similar relation to the upper (Tertiary) diatomaceous shale. The single exception to this grouping is an oil sand which occurs in the sandstones and shales and which lies between the two diatomaceous shale formations but is separated from each of those formations by several hundred feet of barren strata. The upper of the two main zones is by far the more productive, and from the sands overlying the Tertiary diatomaceous shale comes more than 99 per cent of all the oil produced in the Coalinga district. The close association of oil-bearing sands and diatomaceous shales is not unique in the Coalinga region but is the one practically constant feature that may be recognized in all the productive oil fields in the southern half of California. This constant relation has led to the belief that most if not all of the petroleum in the southern half of the State had its origin in the diatomaceous shales. The sandstones in contact with the diatomaceous shales are not everywhere petroliferous; they contain oil in quantity only in places where structural and other conditions have caused it to accumulate. In the Coalinga district the main accumulations lie along a broad anticlinal fold that extends southeastward from the Diablo Range, forming an outlying range of hills east of the town of Coalinga, and also at the upper end of the plunging syncline that lies between the anticline and the main range. In general it may be said that structures of this type appear to govern the occurrence of petroleum in most of the productive fields in the southern half of California. Petroleum is usually found in the anticlinal folds, but in many places, especially along the west side of San Joaquin Valley, oil occurs also in the synclines that parallel anticlines in which the sands are saturated with petroleum.

With this general idea of the manner in which oil occurs at Coalinga in mind the broader features of the region west of Coalinga will be considered to show how far the conditions existing at Coalinga are duplicated.

CONDITIONS IN WALTHAM, PRIEST, BITTERWATER, AND PEACHTREE VALLEYS.

The San Andreas fault divides the region west of Coalinga into two parts, whose structure is so diverse that they may best be treated separately even in this general discussion.

In the mountainous region between the San Andreas fault on the west and the Coalinga district on the east neither of the diatomaceous shale formations with which the oil sands of the Coalinga district are associated occurs. There is present, however, a younger formation of precisely the same type, in which oil might have been formed equally as well as in either of the older shales at Coalinga. Indeed, this shale, which is shown on the map as the Santa Margarita (?) formation, continues southeast and forms part of the huge body of shale from which the oil obtained in the Temblor Range fields is believed to have been derived. The structure in the mountainous region west of Coalinga is, however, very unlike that in the foothills, and the Tertiary rocks, instead of being folded into broad anticlines and synclines as they are along the eastern margin of the Diablo Range, are sharply flexed and faulted and occur in more or less isolated blocks resting on the older formations. Thus the structure is in general not favorable for the collection of oil that may have been derived from the diatomaceous shale, and a duplication of the conditions existing in the Coalinga field is not to be expected. There is a slight chance that oil may have collected beneath a small area lying south of Curry Mountain, but it seems improbable that much oil has concentrated there. Besides the diatomaceous shale there is in this part of the region another mass of sedimentary rocks that must be considered a possible source of petroleum. This mass comprises the dark-colored compact clay shale containing traces of carbonaceous matter that lies in the lower part of the Cretaceous and is especially well exposed on the north side of the upper part of Waltham Valley. This dark clay shale is very like the shale in Colusa and Glenn counties, in northern California, in which seeps of oil occur. However, throughout the region the Cretaceous shale is steeply tilted and nowhere has an attitude favorable for the collection of petroleum.

In the foothills west of the San Andreas fault the lower part of the Tertiary formation contains masses of diatomaceous shale that reach thicknesses of several hundred feet. Asphalt and dry oil sand occur associated with the shale, and this area of low dip should be critically examined as one in which petroleum might have accumulated.

LOCAL AREAS.

AREA SOUTH OF CURRY MOUNTAIN.

GEOLOGY AND ECONOMIC POSSIBILITIES.

In the area of relatively low relief near the southeast corner of T. 21 S., R. 14 E., between the upper part of Jacalitos Creek and Curry Mountain, several structures merge, and, although the dominant feature is the general synclinal structure that produces Waltham Valley, the rocks are folded into a number of small irregular anticlines and synclines. The beds appearing at the surface are of late Miocene age. The older Tertiary beds, which were mapped in the Coalinga report[1] as the Santa Margarita (?), Vaqueros, and Tejon formations, appear to the southeast along Reef Ridge; but to the northwest, about Curry Mountain, the later Miocene strata rest directly upon the Cretaceous, and the older Tertiary formations are not

[1] U. S. Geol. Survey Bull. 398, 1910.

exposed anywhere between that place and Alcalde Canyon. The oil obtained in the main Coalinga field is believed to have originated in the diatomaceous shale which in the Coalinga report was mapped as the upper part of the Tejon formation but has since been proved to be younger than Tejon and probably of Oligocene age and to have migrated from that shale into the sandstones that immediately underlie, overlie, or are bedded with it. The most prolific oil sands are those immediately above this diatomaceous shale, and in general the sands become less productive the farther they are removed from it. Moreover, the seeps of oil that occur farther south, along Reef Ridge, bear a similar relation to the diatomaceous Oligocene (?) shale.

The absence of outcrops of the Oligocene (?) shale and the Tejon formation (Eocene) in the area south of Curry Mountain is therefore of prime importance in considering the possible occurrence of oil in this part of the region. The southernmost exposure of this shale and of the Tejon formation north of Alcalde Canyon is near the San Joaquin Valley coal mine 3 miles due west of Coalinga. From that place to Sulphur Canyon, 10 miles almost due south of Coalinga and about 3 miles east of the southeast corner of the area mapped, the Oligocene (?) shale and the Tejon are covered by younger formations. The western boundary of the shale and the Tejon beneath the mantle of younger formations is of course not known, but as they do not outcrop in the western end of Reef Ridge it seems probable that the Eocene-Cretaceous contact has a general northwest-southeast trend parallel to the structure lines in the outer foothills south of Coalinga, and that the Oligocene (?) shale and the Tejon do not extend far, if at all, west of the axis of the Jacalitos syncline. The Vaqueros and Santa Margarita (?) formations likewise are covered by the later Tertiary strata, but as they are exposed along the south side of upper Jacalitos Creek it is evident that both of these formations extend somewhat farther west than the Tejon and the Oligocene (?) shale. An attempt has been made in the diagrammatic section (fig. 5) to show the probable attitude and relationship of the Tertiary formations in the area southeast of Curry Mountain. The Oligocene (?) shale and Tejon formation are shown extending a short distance west of the axis of the Jacalitos syncline, where they are overlapped by the unconformably overlying Vaqueros formation. From this point they are continuous eastward and probably underlie much of the broad Kettleman Plain. It is believed that petroleum has originated here, as it has in the Coalinga field to the north, in the diatomaceous Oligocene (?) shale that overlies the Eocene Tejon formation and has migrated into the overlying Vaqueros to places where the structure is favorable for its retention. It was pointed out in the Coalinga report[1] that the Jacalitos anti-

[1] U. S. Geol. Survey Bull. 398, pp. 238, 239, 1910.

cline is a favorable place for the collection of such oil. Since that report was written wells drilled along this fold have obtained some light-gravity oil, apparently from the Vaqueros formation, at depths of 3,700 to 4,400 feet. The question now arises whether or not sufficient oil is present to saturate not only the sands along the Jacalitos anticline but also those on the west side of the Jacalitos syncline in a manner analogous to the occurrence of oil in both the Coalinga anticline and syncline.

The general conditions in this area south of Curry Mountain are similar to those in sec. 2, T. 21 S., R. 14 E., a mile or so west of the Westside Coalinga field, where the Vaqueros formation rests directly upon Cretaceous beds. Wells drilled in this northern region obtain oil at a shallow depth from beds in the lower part of the Vaqueros. The conditions in sec. 2 are shown diagrammatically in figure 6.

The oil obtained in the wells in and near sec. 2 probably had its origin largely in the Oligocene (?) shale, migrated into the Vaqueros and thence to the west up the dip, to accumulate finally in the area where the Vaqueros is but slightly tilted. Although there is thus a general similarity between the structure of the area south of Curry Mountain and that of the area above mentioned, north of Alcalde Canyon, it appears rather unlikely that oil has migrated in quantity west of the axis of the Jacalitos syncline to collect in the irregu-

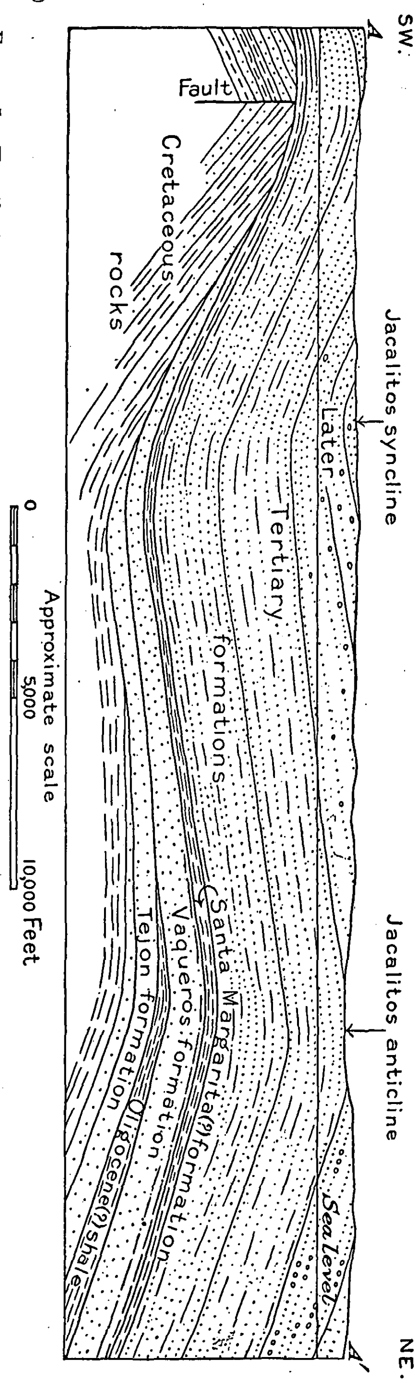


FIGURE 5.—Hypothetical cross section in the Jacalitos Hills, Cal., from a point near the south end of Curry Mountain to the Jacalitos anticline.

larly folded rocks south of Curry Mountain. The Oligocene (?) shale evidently lies much farther east in this area than in the area in sec. 2 north of Alcalde Canyon, and the Jacalitos anticline, along which oil rising from beneath the valley to the east would probably tend to collect, is interposed between the area of low dip near Curry Mountain and most or possibly all of this shale. More direct evidence on this point is the fact that the outcrops of the sands in the lower part of the later Miocene formations, where they are in contact with the Cretaceous on the southeast slope of Curry Mountain, show no trace of oil, whereas the outcrops of the Miocene sands from which the wells in sec. 2, T. 21 S., R. 14 E., derive oil do show such traces. The wells that have been drilled along the Jacalitos anticline,

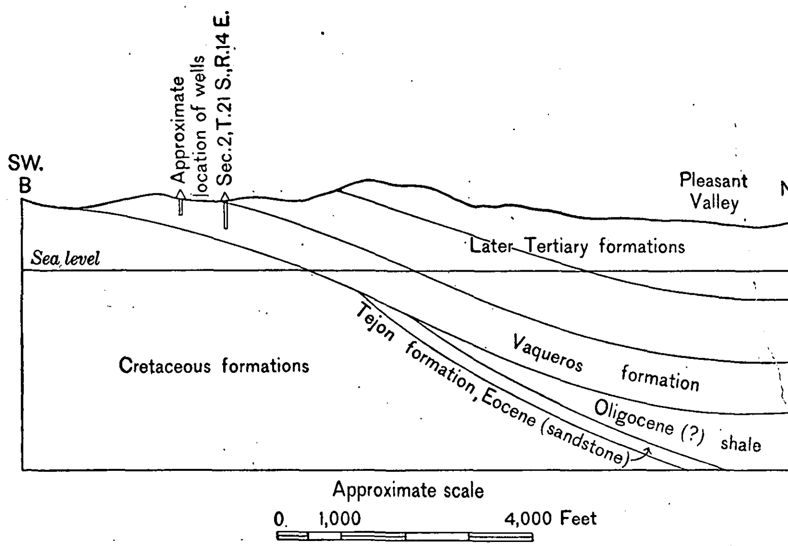


FIGURE 6.—Hypothetical cross section in the western part of the Coalinga oil field, Cal. Adapted from U. S. Geol. Survey Bull. 398, fig. 8, p. 191, 1910.

although they prove the presence of oil, have not yet shown that it occurs in great quantities. Unless the sands along the anticline are saturated with oil it is improbable that they will contain it farther west. Thus any prospecting in the area south of Curry Mountain should await further work along the anticline to the east.

Two formations other than the Oligocene (?) shale might be regarded as possible original sources of oil in the Jacalitos Hills—one the shale that occurs at the top of the Cretaceous in the north end of the Coalinga field and the other the shale of the Santa Margarita (?) formation. It is unlikely, however, that much if any oil which may have formed in either of these shales has collected in the Tertiary beds at the south end of Curry Mountain. The nearest exposures of the Cretaceous shale are in the north end of the Coalinga field. This shale is not exposed south of Coalinga, and in all probability if it underlies the Jacalitos Hills at all it is much farther east than the Oligocene (?) shale and is therefore a much less likely source than that formation. As for the shale of the Santa Margarita (?) it should be noted that where it is exposed on Jacalitos Creek, at the north end of Reef Ridge, that formation is not more than 300 or 400 feet thick. Moreover, this formation evidently decreases in thickness toward the north, beneath the cover of the younger formations, and it is not exposed in the steeply tilted monocline of late Tertiary formations in the foothills north of Coalinga.

WELLS DRILLED FOR OIL.

Wells drilled along the Jacalitos anticline by the Bohemian Oil Co. and the Hub Oil Co. are said to have found oil sands at depths of about 3,700 and 4,300 feet, respectively. Farther southeast along the same fold the well of the Azores Oil Co. is said to have obtained oil at 3,500 feet. In the Jacalitos syncline to the west several wells have been drilled, but so far as the writers are aware none of them penetrated the strata of the later Tertiary formation and reached the horizons at which oil sands, if they exist in the region, might be expected to occur.

About 13 or 14 years ago three wells were drilled along the upper part of Jacalitos Creek. Two were put down by the Whale Oil Co. in the SE. ¼ sec. 4, T. 22 S., R. 14 E., one to a depth of 650, the other 600 feet. Salt water was obtained in the deeper well. Near the south line of sec. 32, T. 21 S., R. 14 E., the Venus Oil Co. drilled a well about 1,500 feet deep without obtaining oil. These three wells could hardly have been drilled in more disadvantageous places, for the Tertiary beds are steeply tilted and faulted, offering no favorable structure for the concentration of oil should it have occurred disseminated through the strata.

WALTHAM AND PRIEST VALLEYS.

The Tertiary formations in Waltham and Priest valleys lie in a structural depression that trends diagonally across the Diablo Range. The structure, though in general synclinal, is complicated, especially on the southwest, by numerous small folds and faults that have infolded or dropped blocks of the Tertiary beds into the Franciscan. This structure is not specially favorable for collecting any petroleum that may have occurred in small quantities throughout the rocks, nor are there here any large areas underlain by diatomaceous shale from which oil might be derived. The diatomaceous shale of the Santa Margarita (?) formation has at best relatively small distribution, even though it underlie most of the region where the later Miocene formations appear at the surface. The tremendously thick section of dark carbonaceous shale that forms the lower part of the Cretaceous on the north side of Waltham Valley might be regarded as an original source of petroleum, but its high and regular dips afford no favorable structure for the accumulation of oil, even if it were originally present.

Indications of oil have been reported near the northwest corner of sec. 28, T. 20 S., R. 13 E., along the fault that extends northwest-southeast through the hills on the north side of Waltham Valley, about a mile west of Fresno Hot Springs. The writers were unable to confirm this report but are inclined to credit it. Such oil may have risen either from the dark carbonaceous shale of the Cretaceous or from the diatomaceous shale of the Santa Margarita (?), which supposedly lies beneath the later Tertiary strata north of Waltham Creek. Of the two possibilities the first seems the more probable.

Wells have been drilled for oil at two places on the north side of Waltham Valley near the reported seep. Just south of the southeast corner of sec. 20, T. 20 S., R. 13 E., five wells were put down within a few hundred feet of one another 9 or 10 years ago by the Echo Oil Co. The deepest well, No. 2, is said to have been drilled to a depth of 1,400 feet. Two of the wells are said to have obtained small quantities of gas and oil, and it is commonly reported that as much as 5 or 6 gallons of light-gravity oil has been bailed out at a time. About a mile to the southeast, near the center of sec. 33, T. 20 S., R. 13 E., is the Warthan Oil Co.'s well. Drilling has been carried on here at various times since 1909 but was suspended in September, 1913, for lack of funds. This well and those of the Echo Oil Co. are close to a large fault, along which the strata are steeply tilted and much fractured. If oil did occur in the rocks, it probably would have tended to migrate from the beds that lay relatively close to the fault into the crushed zone, but the position and attitude of the more distant rocks make it improbable that oil from any very great thickness of beds would have migrated in this manner. Also, the beds along the fault are so steeply tilted and so broken that they offer a ready avenue of escape to the surface for any oil which might be contained in them.

BITTERWATER AND PEACHTREE VALLEYS AND FOOTHILLS TO THE WEST.

GEOLOGY.

West of the San Andreas fault zone the beds mapped as upper Miocene rest directly upon the eroded surface of the granite. In the area shown on the map these beds have a maximum thickness of about 3,300 feet and comprise two formations, of which the lower, made up of sand, clay, gravel, and diatomaceous shale and filled with marine fossils, is believed to be the equivalent of the Santa Margarita formation, and the upper, composed of material that was probably laid down in lakes or subaerially, is the equivalent of the Tulare formation. West of Peachtree Valley the upper of the two formations is relatively unimportant, appearing only in isolated areas along the crests of the ridges as a cap less than 200 feet thick. The beds that are comprised in the formation that is considered the equivalent of the Santa Margarita are variable in character, ranging from coarse conglomerate to fine diatomaceous shale, but for the most part are fine grained. Near Lonoak and in Bitterwater Valley the lower 1,000± feet is composed of diatomaceous shale, which forms prominent white outcrops that are especially noticeable about 2 miles northwest of Lonoak post office. Shale of this type forms the lower part of the Tertiary along the west side of Bitterwater Valley, in the north end of Mustang Ridge, in small areas near the east corner of the Peachtree ranch, and in much of the Topo ranch northwest of the area mapped. In many other parts of the region, however, sandy or even gravelly beds, such as those exposed near the asphalt quarry west of Lonoak, rest upon the granite. Practically no diatomaceous shale appears resting upon the granite near its exposures in small areas 4 miles southwest of Lonoak. The variability in the lithology of the lower part of the Tertiary is well shown along the north side of San Lorenzo Creek west of the granite that is exposed at the edge of the area mapped. Possible explanations of the variability in the thickness of the diatomaceous shale appear to be (1) that the Tertiary beds were laid down upon a very uneven surface of granite and that in parts of the region the lower beds were not deposited; (2) that the shale actually grades laterally into coarser materials; (3) that the diatomaceous shale is older than the clay and shale and is separated from them by an unconformity. The most probable explanation seems to be that the variability in the thickness of the shale is due both to lateral variation in character and to the uneven surface upon which it rests. Sandy beds intercalated with the diatomaceous shale contain fossils apparently of precisely the same type as those in the overlying sandy beds, and it seems improbable that any considerable time intervened between the deposition of the two divisions. The presence or absence of the diatomaceous shale is of considerable importance, for the seeps of oil appear only in those areas where it has considerable thickness.

The Tertiary strata that cover the granite have not been deformed to any very marked degree west of the San Andreas fault zone. West of Peachtree Valley nearly to the edge of the area mapped this cover may be thought of as a sheet, very slightly wrinkled along irregular lines and in general dipping slightly toward the northeast. Farther west the dip changes; along the edge of Salinas Valley it is in general toward the west, carrying the beds beneath the valley. Between Peachtree Valley and the San Andreas fault zone is a shallow syncline, which the writers have termed the Peachtree syncline. This fold starts near the center of the Peachtree ranch and continues northwest through the Topo ranch, beyond the area mapped. The east flank of this syncline is terminated by the San Andreas fault zone, along which the beds of diatomaceous shale in the lower part of the later Miocene formations are so tilted that they are nearly vertical. North of Lonoak the southwest flank of the syncline merges with the area of low irregular dips along the foothills east of the Salinas Valley, but along the Peachtree Valley it is apparently terminated by a fault. It is in this synclinal basin that most of the drilling for oil has been done. Along the San Andreas fault a zone varying from three-quarters to 1 mile in width is traversed by innumerable faults and the rocks are greatly shattered. In this zone rocks of the Franciscan and later formations are intermingled in irregular masses, and along the west side steeply tilted beds of diatomaceous shale occur. Through this zone of fracture oil contained in the rocks has found an easy passage to the surface. Several wells have been drilled along it, but none of them have found any considerable reservoir of oil.

SURFACE INDICATIONS OF PETROLEUM.

In several places in Bitterwater and Peachtree valleys oil impregnates the surficial sandy beds that lie in the San Andreas fault zone or that rest upon the granite. The largest of these outcrops occurs at the Mylar asphalt quarry, in secs. 14 and 15, T. 19 S., R. 9 E., about 2 miles west of Lonoak. The basal 25 to 50 feet of the later Miocene here is a coarse arkosic sand or grit that was evidently derived from the granite upon which it rests. The outcrops of this sand for a distance of about one-half mile are impregnated with tarry oil or asphalt, the amount contained varying from place to place. Where the outcrops are weathered and unbroken the sand is light brown and friable, but in the newer faces of the quarry the sand is plastic from the amount of tar it contains, and in one place thick oil slowly oozes out along its contact with the underlying granite. The oil sand or asphalt is quarried from time to time and used in repairing the roads about King City. Most of the sand is of medium coarse grain, and the material is used directly upon the roads without the addition of more sand.

Oil-saturated sands outcrop at two places near the southeast corner of the Peachtree ranch, in what corresponds to the SE. ¼ sec. 22 and the SW. ¼ sec. 25, T. 20 S., R. 11 E. At the first-named locality a massive sandstone that stands almost vertical occurs on the west side of an area of much contorted diatomaceous shale. The relationship of the sandstone and shale is not entirely clear, as the rocks are considerably faulted, but the sandstone is believed to be stratigraphically above most or possibly all of the shale. The sandstone is impregnated with heavy oil, which slowly seeps out in the bottom of one of the steep arroyos. About 1¼ miles southeast of this seep a sandstone 50 to 60 feet thick, bedded with the diatomaceous shale that occurs near the base of the Tertiary, is impregnated with oil. This bed appears to be a sandy lens in the upper part of the diatomaceous shale. It lies at the western edge of the San Andreas fault zone, is much fractured, and is truncated on the east by a fault that brings it into contact with the clay in the Tulare formation.

Where the San Andreas fault crosses Alvarez Creek, in sec. 32, T. 18 S., R. 10 E., an outcrop of much fractured coarse arkosic sandstone in the Tulare formation is stained by petroleum, and wells less than 100 feet deep sunk here have yielded a little light-gravity oil.

About 13 miles due north of King City, approximately in sec. 29, T. 17 S., R. 8 E., at the Matthews asphalt quarry, a bituminous sandstone outcrop lies, like that at the Mylar quarry near Lonoak, between outcrops of granite and of diatomaceous shale. This sandstone may underlie the diatomaceous shale, as was suggested by Eldridge,[1] but as the oil sand is limited to the small gulch tributary to Chalone Creek and contains besides granitic material an appreciable number of diatomaceous shale fragments, the writers suggest that it is probably a stream terrace deposit impregnated with and cemented by thick tarry oil that seeped out of the lower part of the diatomaceous shale. The beds of sand and gravel impregnated with oil are of very uneven grain and on the whole are much coarser than those at the Mylar quarry.

WELLS DRILLED FOR OIL.

The following wells have been drilled for oil in and near Bitterwater and Peachtree valleys:

Nonpareil No. 1, sec. 32, T. 18 S., R. 10 E.
Nonpareil No. 2, sec. 32, T. 18 S., R. 10 E.
Nonpareil No. 3, sec. 32, T. 18 S., R. 10 E.
Lonoak No. 1, sec. 7, T. 19 S., R. 10 E.
Lonoak No. 2, sec. 31, T. 18 S., R. 10 E.
Alvarez No. 1, sec. 33, T. 18 S., R. 10 E.
Le Franc No. 1 (Standard Oil Co.), Topo ranch, in what corresponds to sec. 33, T. 17 S., R. 9 E.
Tompkins No. 1 (Standard Oil Co.), sec. 19, T. 19 S., R. 10 E.
Tompkins No. 2 (Standard Oil Co.), sec. 19, T. 19 S., R. 10 E.
Landrum No. 1 (Standard Oil Co.), sec. 28, T. 19 S., R. 10 E.
Doheny well, sec. 14 or 15, T. 19 S., R. 9 E.
Miller No. 1 (Union Oil Co.), Peachtree ranch, in what corresponds to sec. 24, T. 20 S., R. 10 E.
Salinas No. 1, sec. 9, T. 19 S., R. 10 E.

[1] Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 1, pp. 409–410, 1901.

The Nonpareil wells were drilled about 13 years ago near the seep where the San Andreas fault crosses Alvarez Creek. Previous to the drilling of the main wells, two wells were drilled by hand, the deeper of which is said to have obtained light-gravity oil at 60 to 70 feet. At the time of the writers' visit it had caved below the 55-foot depth and was dry of oil, although containing considerable gas. Of the three larger wells, No. 1 is said to have reached a depth of 1,038 feet without obtaining more than a trace of oil. Well No. 2 was drilled 653 feet and obtained oil between 400 and 520 feet. Oil now stands in the hole, but the well has never produced. Well No. 3 reached a depth of 1,300 feet, having been drilled through "a great mixture of rocks," but obtained no oil.

Lonoak well No. 1 was sunk about 2,700 feet and is said to have reached granite at that depth without having encountered a trace of oil. Well No. 2 reached a depth of 3,009 feet, getting a little tarry oil at 600, 800, and 1,800 feet. A few barrels of oil is said to have been pumped.

The Salinas well is said to have been drilled to 450 feet and at that depth to have found a little very heavy oil like that in Lonoak well No. 2.

The Doheny well, near the southwest corner of sec. 14, T. 19 S., R. 9 E., starts about 750 feet south of the outcrop of the oil sand at the Mylar asphalt quarry. It is said to have reached the granite at 900 feet without having found oil. The lack of success of this well is striking and shows the local character of the oil sand that is quarried as asphalt.

The Alvarez well was started a few hundred feet south of the old Nonpareil wells and drilled to a depth of 900 feet but obtained no oil.

The Le Franc well of the Standard Oil Co., at the head of Bitterwater Valley, within a few hundred feet of the San Andreas fault line, was drilled to a depth of more than 2,000 feet. It is said to have penetrated considerable oil sand but produced no oil. The fractured condition of the beds here prohibits an estimate of the stratigraphic position of the oil sands penetrated.

The two Tompkins wells and the Landrum well of the same company were drilled in Peachtree Valley and are said to have reached a "hard gray sand" without finding more than a trace of oil. It may be that the "gray sand" is an arkosic sand derived from the granite and is similar to that at the asphalt quarry west of Lonoak, but the writers believe that it is more probably granite.

The Miller well of the Union Oil Co., near the west edge of the Peachtree ranch, along the road from Peachtree Valley to Salinas Valley was drilled to a depth between 2,500 and 2,600 feet, but no oil was found.

ECONOMIC POSSIBILITIES.

Along the San Andreas fault the beds are broken and all the formations are so intermingled in small irregular masses as to form a structure exceptionally unfavorable for the accumulation and retention of petroleum. It is true that oil contained in the solid rocks in the immediate vicinity would probably work its way into the crushed zone, but it is difficult to believe that it would be held there in quantity and would not work its way to the surface. Thus, although seeps of oil occur along this zone, and although wells such as Lonoak well No. 2 and the Salinas well have obtained small quantities of oil, the presence of oil beneath the surface in sufficient amount to make drilling profitable seems very unlikely. Also, the experience in other California fields shows that oil contained in rocks so badly fractured as these is of variable character and that much of it is of heavy gravity. Thus the oil found in the Lonoak and Salinas wells is probably typical of the oil that does occur, despite the fact that small quantities of light-gravity oil have been found in shallow wells on Alvarez Creek.

Of the 3,000 feet or more of Miocene beds which are infolded in the Peachtree syncline near Lonoak the lower 1,000 feet or so is largely diatomaceous shale. This shale is continuous southward but seems to become more sandy in that direction. That the beds associated with the shale contain some oil is shown by the outcropping oil sands in the southeast corner of the Peachtree ranch and by the results obtained in the wells near the mouth of Lewis Creek. However, the writers believe it doubtful that oil has accumulated here in any considerable amount. The syncline is structurally isolated, being bounded sharply on the east by the San Andreas fault zone and on the southwest by the granite and probably by a fault extending along Peachtree Valley. Thus it seems improbable that oil could have collected in this basin from the rocks underlying any very extensive area. Any oil which might have been formed in the beds beneath Salinas Valley would probably not travel eastward beyond the area west of Peachtree Valley, in which the Tertiary beds are wrinkled irregularly. Moreover, except in a small area near the mouth of Lewis Creek, where the beds are slightly domed, the general synclinal structure is not favorable for the collection of petroleum. Even the doming cited is really so slight and lies so close to the badly fractured San Andreas fault zone that it is improbable that oil has collected in it. The wells which have been drilled here have pretty thoroughly tested the area, and it is believed that further drilling, even along the small fold mentioned above, will fail to disclose any extensive accumulations of oil.

The low foothills between the Peachtree and Salinas valleys present many of the features exhibited by the large productive fields in California, and in this area alone, of all the region studied, does there appear to be a possibility of obtaining oil. The factors supporting the theory that oil may have accumulated here in considerable amounts may be listed as follows: (1) Some oil is undoubtedly present, as is shown by the outcropping oil sand at the asphalt quarry near Lonoak and at the south end of the Peachtree ranch; (2) diatomaceous shale, which is regarded as the ultimate source of the oil in this part of the State, is bedded with, overlain by, and underlain by porous sandstone, which, although mostly of rather fine grain, would serve as an excellent reservoir for oil; (3) the sandy beds are somewhat lenticular and are intercalated with clay or shale, thus probably furnishing local reservoirs of porous material more or less completely inclosed in impervious walls; (4) the beds are tilted slightly and irregularly, locally forming small, low structural domes; (5) to the west is the broad synclinal Salinas Valley, under which lies part at least of the thick mass of diatomaceous shale that outcrops along the Santa Lucia Range on the west side of the valley. Thus there is an area of considerable size from which oil might have risen to collect in the slightly folded rocks.

Although the broader features of the stratigraphy and structure appear to favor the hypothesis that oil has accumulated in the foothills west of Peachtree Valley, two important questions remain to be answered, and to neither of them does the answer seem favorable, so far as may be judged from the areal geology. They are (1) whether the oil, though undoubtedly present, was formed in quantities in any way comparable with those found in the southern end of the San Joaquin Valley; and (2) whether, if any considerable quantity of oil was formed beneath the valley, it would have collected in the beds in the foothills on the east side in reservoirs of sufficient size to be commercially valuable.

It seems probable that the first question must receive a negative answer. Seeps of oil and dry oil sands occur not only in the region described but also to the southeast, in the Parkfield region, and at intervals for several miles on the west side of the valley. In other words, the outcrops of the Tertiary rocks on both sides of the basin show evidence of petroleum, and it is reasonable to suppose that the beds in the center of the basin, now covered by alluvium, also contain or at one time contained it. The basin occupied by sedimentary rocks here is, however, of much smaller area than that at the southern end of the San Joaquin Valley; the diatomaceous shale in it is far thinner than that in the Temblor Range and along the east side of the Salinas Valley is somewhat irregularly developed, owing, in part, to its having been laid down upon a very irregular surface of granite and probably also in part to the fact that it is replaced in some areas by sandy beds. This irregularity is well shown along San Lorenzo Creek. Near Lonoak the lower 1,000 feet or so of the later Miocene is fairly pure diatomaceous shale, but less than 2 miles downstream sand and sandy clay, in lithologic character precisely like the beds overlying the diatomaceous shale near Lonoak, rest directly upon the granite. Also, near the small granite exposures some 4 miles southwest of Lonoak the sedimentary beds are entirely sand and sandy clay. Thus if the diatomaceous shale is regarded as the ultimate source of the oil it is unreasonable to suppose that so great quantities of oil were formed here as were formed in the southern end of the San Joaquin Valley.

The oil seeps in the region studied are very closely associated with the diatomaceous shale, and practically none is known in an area in which the shale has not considerable development. It is not unreasonable to suppose that beneath the alluvial filling in Salinas Valley the diatomaceous shale has as irregular a development as it has where exposed in the area studied. If such is the case, unless there is some special cause for its further migration, any oil which may have originated in the shale would probably not move farther than the sandy beds interstratified with or immediately adjacent to the shale. Thus the tendency would be for the formation of a number of small local concentrations.

So far as the effect of the structure upon a possible accumulation of oil is concerned, the most notable feature in the foothills between Peachtree and Salinas valleys is the lack of any well-defined fold at all comparable with those which, south of Coalinga, border the San Joaquin Valley on the west and along which lie the productive oil fields. Instead of being strongly folded the Tertiary beds along the east side of Salinas Valley are but slightly tilted, in much of the area less than 2°. The importance of this difference in structure can hardly be overestimated in considering the possibility of oil having accumulated in considerable quantity.

Along the edge of Salinas Valley the dip is in general southwest, but near the border of the area mapped it is northeast. The change does not take place along a line, but rather along an ill-defined belt several miles in width, or it perhaps may best be described as being marked by a number of short irregular domes of which three appear in the area mapped. One occurs near the asphalt quarry west of Lonoak, where the later Miocene beds dip 2° to 7° away from the granite. The second occurs west of the Peachtree ranch, where a line trending northwest-southeast through secs. 16 and 22, T. 20 S., R. 10 E., separates the beds that dip about 2½° SW. from those that dip approximately as much northeast. The third occurs just northwest of the isolated outcrop of granite some 4 miles southwest of

Lonoak. These uplifts are so gentle that their axes can not well be designated by a definite line, but their position is indicated by the dips given on the map.

In San Joaquin Valley the sandy beds along the anticlines have served as reservoirs for oil that is believed to have once been contained in beds that extended over large areas. Much of the oil probably originated beneath San Joaquin Valley, worked its way up the rise, and accumulated in the upper parts of the folds. On the east side of Salinas Valley, however, no such folds dominate the structure and there appears to be no reason why oil that may occur disseminated through the rocks over a wide area should accumulate in considerable amounts in a single small area. On the contrary, oil which may have originated beneath the valley would probably tend to remain in the upper parts of the numerous low, faint domes or wrinkles. Moreover, the diatomaceous shale is much thinner along Salinas Valley than it is along the western border of San Joaquin Valley; hence it is even more necessary in Salinas than in San Joaquin Valley that a structural feature which favors the accumulation of oil should have tributary to it a large area from which oil may be drained.

In conclusion it may be said that the irregular structure, the irregular distribution of the diatomaceous shale, and the lenticular character of the sandy beds all seem to indicate not that oil has accumulated in any considerable quantity in few localities but rather that it has accumulated in small amounts at a number of places in the upper parts of low folds or domes. It is not at all unlikely that wells drilled along the axes of the low anticlinal folds that lie between Salinas River and Peachtree Valley will find oil. It is to be expected, however, that the area that may prove productive is very irregular in outline, and that the amount of oil in the producing wells will be small. Thus for many years to come the cost of prospecting this region with the drill will probably be much greater than the value of the oil that may be obtained.

So far no well has adequately tested the area west of the Peachtree Valley. The well most advantageously placed is the Miller well of the Union Oil Co., which was drilled near the southwest side of the Peachtree ranch, about a mile east of the line of change in dip, in secs. 22 and 16. Although the test would have been more satisfactory had the well been located farther west, still the failure to obtain oil in it goes far to prove that any oil sands which may occur here are of small extent. Also, the outcrops of granite some 4 miles southwest of Lonoak are significant, for although there is here a slight fold or dome comparable with that near Lonoak, yet the beds, unlike the Tertiary sands at Lonoak, show not the slightest trace of oil.

OUTLYING DISTRICTS.

The following brief notes regarding the geology and possible occurrence of oil in the Topo ranch, which lies beyond the boundary of the area shown on the map, in the upper part of the valley of San Benito River, are based on hurried visits made during the course of the work.

TOPO RANCH.

The Peachtree syncline continues as a broad, shallow fold northwestward beyond the area shown on the map, passing through the Topo ranch. On the east the syncline is terminated by the San Andreas fault zone and on the west by the granite which here appears at the surface in the Gabilan Range. Along the west side of the syncline the lower part of the Tertiary section consists of chalky white diatomaceous shale having a maximum thickness of not more than 1,000 feet. Upon the shale rest a few hundred feet of sandy beds, which constitute both the Santa Margarita and the Tulare formations. The beds for half a mile on either side of the axis of this syncline dip at angles of less than 5° and on the west flank of the fold at angles of less than 10° as far as the granite hills. The Matthews asphalt quarry (see p. 147) is on the west flank of this syncline at the contact between the granite and overlying Tertiary beds.

Five wells have been drilled by the Standard Oil Co. in this syncline on or south of the Topo ranch. Some of them were drilled through the Tertiary beds to the underlying granite, but none found more than a trace of oil or gas. Their names and location are given below:

Dunne No. 1, Topo ranch, west of Dunne ranch house.
Dunne No. 2, Topo ranch.
Brown No. 1, sec. 15, T. 17 S., R. 8 E.
Stone No. 1, sec. 27, T. 17 S., R. 8 E.
Leonard No. 1, sec. 28, T. 17 S., R. 8 E.

The Leonard well, drilled about one-third of a mile east of the Matthews asphalt quarry, started in the diatomaceous shale and struck heavy oil and tar not far above the granite.

This synclinal basin in and north of the Topo ranch presents few features which would make it appear probable that oil has collected in it in considerable quantity. It is isolated, being bounded sharply on the northeast by the San Andreas fault zone and on the west by the granite of the Gabilan Range, and is thus almost cut off from the Tertiary rocks in Salinas Valley. These conditions make it difficult to believe that the syncline has acted as a catchment basin for oil drawn from great stretches of rocks in the surrounding territory. Moreover, the synclinal structure is not especially favorable to the concentration of oil, as any oil that did exist in this rock would be forced up the rise and would appear at the surface, as it has at the Matthews asphalt quarry. Finally the wells that have already been drilled have pretty thoroughly tested the area.

SAN BENITO RIVER VALLEY.

East of San Benito River, near the southwest corner of T. 17 S., R. 10 E., later Miocene beds, approximately the equivalent of the Etchegoin formation of the Coalinga region, dip rather regularly 20°–30° SW. About a mile northeast of the area mapped these beds are broken by a fault which is approximately parallel to the San Andreas fault. A short distance northeast of this fault Cretaceous, Eocene (?), and Franciscan (Jurassic?) rocks appear. The upper part of the Miocene beds is mainly massive arkosic sandstone filled with marine fossils. Beneath these beds are alternating beds of reddish and greenish clay and gravel, much like the beds that appear along the axis of the Vallecitos syncline, about 10 miles away on the opposite side of the Diablo Range, and presumably of upper Miocene age.

There seems to be no reasonable chance of obtaining oil in this part of the San Benito River valley. So far as known no seeps of petroleum occur here, although the rocks are broken and are in places much shattered by faults, so that oil certainly would have had abundant opportunity to reach the surface if it ever had been present. Also, so far as known, no masses of sedimentary rocks that contain any considerable amounts of organic material, such as diatomaceous or carbonaceous shale, occur in this region. Finally, the structure is not especially favorable to the accumulation of oil.

It has been said that the value of this region as oil-producing territory is shown by the fact that it lies midway between Bitterwater Valley and the Vallecitos, in both of which seeps of oil occur. This can hardly be considered a valid argument, as the area is separated from the Bitterwater region by the San Andreas fault and from the Vallecitos by a great mass of Cretaceous and Franciscan (Jurassic?) rocks, which lie stratigraphically below the oil-bearing rocks.

The McMurtry-Hoeppner well, near the west line of sec. 32, T. 17 S., R. 10 E., is on James Creek, a tributary of San Benito River from the northeast. The well starts in the fossiliferous late Miocene beds and, when visited in November, 1913, had been drilled to a depth of 1,462 feet and had apparently reached the clay and gravel that form the lower part of the upper Miocene. No trace of oil had been obtained.

COAL.

OCCURRENCE AND AGE.

Coal occurs in the Tertiary beds in the Priest Valley syncline and at several places in the hills on the south side of Waltham Valley. About 4 miles south of the summit of Smith Mountain is the Stone Canyon mine, at which coal has been mined at irregular intervals for many years. The coal beds within the boundaries of the area shown on the map have been prospected at a number of places, but when visited in the later part of 1913 none of the prospects remaining open furnished a good section of the beds and no fresh samples of the coal were obtained. Although no attempt was made to study the coal beds in detail, the following facts, which were brought out in the course of the work, regarding the age of the different carbonaceous beds and their general distribution are believed to be of sufficient importance to record. The points of chief interest are that coal occurs at three horizons in this part of the Diablo Range—in the Eocene, the lower Miocene, and the upper Miocene; that the coal in Priest Valley is not, as is commonly thought, the same as that in Stone Canyon but is younger and apparently of much poorer quality; that the coal occurs in small isolated structural basins and not, as has been reported, in a continuous bed or succession of beds extending from Stone Canyon northwestward to the valley of San Benito River.

EOCENE COAL.

Coal occurs in Eocene beds exposed west of Coalinga and was mined there some 20 years ago. In 1893 approximately 400 tons were shipped, principally to Fresno, from the San Joaquin Valley and California mines.[1] The enterprise, however, did not prove profitable, and mining was discontinued even before oil was discovered in the region in quantity.

The coal occurs in the white quartzose sandstone of the Tejon formation in thin, discontinuous beds, most of them less than a foot thick, although it is said that the "big vein" in the old mines is about 4½ feet thick.

Coal occurs in the Eocene sandstone (Tejon formation) at many places along the foothills on the east side of the Diablo Range northwestward from Coalinga, but principally on the south side of the Vallecitos in T. 17 S., Rs. 11 and 12 E. On the west side of the summit of the Diablo Range in secs. 20 and 21, T. 17 S., R. 10 E., 2 miles north of the area shown on the map, is the Trafton mine, which

[1] California State Mining Bureau Twelfth Rept. California State Mineralogist, pp. 50–54, 1894.

was described briefly by Campbell.[1] The coal occurs in sandstone that, as nearly as could be determined in the brief time spent in the region, occupies about the same stratigraphic position as the coal-bearing beds in the Vallecitos, some 6 miles to the east, and, although no diagnostic fossils were found in the coal-bearing beds, the coal at the Trafton mine is probably of Eocene age.

LOWER MIOCENE COAL.

The coal at Stone Canyon, in the center of T. 22 S., R. 13 E., has been described briefly by Arnold[2] and Campbell.[3] It occurs in the lower part of the Vaqueros formation (lower Miocene) close to the contact with the Cretaceous rocks and the Franciscan formation (Jurassic?), upon which the Vaqueros rests unconformably. On the opposite (northeast) side of the Diablo Range the lower part of the Vaqueros is exposed in the area discussed in the present report on both flanks of the syncline that trends northwest on the north side of Smith Mountain. The lower beds are best exposed on the south flank of the syncline from the head of Jacalitos Creek, in sec. 35, T. 21 S., R. 13 E., northwestward through secs. 34, 33, and 28, and on the north flank of the fold in the NW. ¼ sec. 21 of the same township just west of the trail that leads from Waltham Valley to Bourdieu Valley. In both places the beds are rather steeply tilted, dipping 40°–75°. These dips are, however, restricted to a relatively narrow belt, and in much of the intervening area, closer to the axis of the syncline, the Vaqueros is tilted less than 30°.

The coal-bearing portion of the formation lies below the massive calcareous sandstone which outcrops along the crest of the ridge and which forms the top of Smith Mountain and Smith Pinnacles. It varies greatly in thickness and in character and is evidently a near-shore deposit that was laid down upon a very uneven surface of Franciscan, Knoxville, and Chico rocks. This part of the Vaqueros weathers easily and, occurring as it does beneath a massive cliff-forming sandstone, furnishes few good exposures. At the head of Jacalitos Creek, in the SW. ¼ sec. 35, T. 21 S., R. 13 E., the beds beneath the massive calcareous sandstone have a thickness of at least 200 feet. The upper 100 to 150 feet is composed of beds of greenish or bluish conglomerate formed largely of fragments of Franciscan rocks, beneath which is 75 to 100 feet of carbonaceous and perhaps in part diatomaceous shale. The outcrop of this shale

[1] Campbell, M. R., Coal in San Benito County, Cal.: U. S. Geol. Survey Bull. 431, p. 243, 1911.

[2] Arnold, Ralph, Coal in the Mount Diablo Range, Monterey County, Cal.: U. S. Geol. Survey Bull. 285, pp. 223–225, 1906.

[3] Campbell, M. R., Coal of Stone Canyon, Monterey County, Cal.: U. S. Geol. Survey Bull. 316, pp. 435–438, 1907.

is apparently terminated on the south by a fault that has brought the shale into contact with sandy shale and somewhat concretionary sandstone whose exact stratigraphic position is not known. The carbonaceous shale is, however, not far above the base of the Vaqueros. On the north side of this syncline, in the NW. ¼ sec. 21, T. 21 S., R. 13 E., the following section is exposed. The thicknesses given are estimates but are probably accurate within 10 per cent.

Incomplete section of carbonaceous beds in lower part of Vaqueros formation in NW. ¼ sec. 21, T. 21 S., R. 13 E.

	Feet.
A. Sandstone, massive, somewhat calcareous; basal bed filled with large oyster shells. Probably the lower part of the sandstone that forms Smith Pinnacles.	
B. Sandstone, less massive than bed A, light gray, weathering to yellow-brown	10
C. Sandstone, somewhat carbonaceous, rather shaly, weathering red-brown. Bed 1 foot thick 6 feet above base is filled with large oyster shells	16
D. Sandstone, light gray, not notably carbonaceous	2½
E. Sandstone, somewhat shaly and carbonaceous, like bed C	4
F. Conglomerate and clay, reddish, purplish, and greenish. Purple beds almost wholly minute fragments of serpentine and basic igneous rocks. Pebbles largely flat fragments of Franciscan, rarely over 3 or 4 inches long	35–40
G. Sandstone, mainly shaly and carbonaceous, with a few massive concretionary beds. Somewhat like bed E. Base not exposed	15+

The beds lying beneath the coal and mapped as part of the Vaqueros formation have not yet yielded diagnostic fossils. At the Stone Canyon mine the coal rests upon clay shale somewhat different from any beds of the Vaqueros above the coal, and judged by this section alone there seems to be some ground for the view held by many who have examined the mine that the clay and coal are parts of a formation older than the Vaqueros. However, on the northeast side of the Diablo Range the carbonaceous beds are underlain in places by gravel and coarse sandstone precisely like those which overlie the coal and which contain typical lower Miocene fossils. Thus there seems to be no reason to doubt that the coal is of lower Miocene age, as it was regarded by Arnold.[1]

Several prospect tunnels have been run into the lower part of the Vaqueros in the north half of secs. 33 and 34, T. 21 S., R. 13 E., in the valley of a stream tributary to Alum Creek. According to Mr. V. H. Crump the last work here was done in 1909, when a San Jose company ran a 200-foot tunnel to crosscut the coal. The tunnel

[1] Arnold, Ralph, Coal in the Diablo Range, Monterey County, Cal.: U. S. Geol. Survey Bull. 285, pp. 223–225, 1906.

started in beds a little below the massive calcareous sandstone of the Vaqueros and ran south about 200 feet into the Franciscan formation without finding coal. On the west side of the same creek near the line between secs. 33 and 34 are other caved prospect tunnels, which, to judge from the dump, were at least 200 or 300 feet in length. No definite information was available concerning them, but fragments of coal and carbonaceous shale lie in the dump. On the east side of the creek a prospect having about 200 feet of tunnel and incline was dug by Mr. Crump eight or nine years ago.

UPPER MIOCENE COAL.

Carbonaceous shale and thin beds of coal occur in the western end of the Priest Valley syncline, in T. 20 S., R. 12 E. On the south flank of the syncline outcrops of very carbonaceous shale and of coal are traceable from the southwest corner of sec. 25 northwestward through secs. 26, 27, 22, 21, and 17 to the center of the S. ½ sec. 8, and thence eastward through secs. 9, 10, and 11 nearly to the center of sec. 14. The easternmost outcrop of these beds that was discovered on the north flank of this syncline occurs along the divide between Priest and Waltham valleys, although carbonaceous beds are reported to outcrop about a mile southeast of that divide, in the N. ½ sec. 24.

The carbonaceous beds occur within 1,500 feet of the top of the upper Miocene. About 150 feet above them is a fossiliferous zone that contains abundant specimens of the scallop shells *Pecten wattsi*, *Pecten nutteri*, and *Pecten coalingensis* and of *Thais* (*Purpura*) *etchegoinensis*. This fossiliferous zone occurs in the upper part of the Etchegoin formation in the Coalinga region. For the most part the carbonaceous beds form poor outcrops, weathering characteristically to a loose, deeply cracked clayey soil that supports a somewhat better growth of grass than the more sandy beds. They are probably best exposed south of Priest Valley post office, where the following section was measured:

Section of carbonaceous beds in NE. ¼ sec. 21, T. 20 S., R. 12 E., a quarter of a mile south of Priest Valley post office.

	Feet.
Sandstone, massive, gray, cross-bedded; fossiliferous zone containing *Thais* (*Purpura*) *etchegoinensis*, etc., in lower 50 feet	275
Shale, greenish brown; contains numerous ironstone concretions and a thin bed of lignitic shale near base	60
Sandstone, reddish gray, concretionary, poorly consolidated	8
Shale, friable, greenish, stained reddish by iron	11
Shale, brownish, carbonaceous, very fissile	5
Shale, drab, carbonaceous	1
Shale, brownish red, carbonaceous	3

	Feet.
Shale, bluish, soft and fissile	4
Shale, brown, carbonaceous	6
Sandstone, gray, interstratified with fissile gray shale	15
Shale, soft and fissile; alternating bluish and brownish beds	15
Sandstone, somewhat pebbly; a few thin beds of brown shale	65
Shale, gray, iron stained; contains 2 to 4 inch beds of carbonaceous shale	70
Shale, brown, carbonaceous; thin partings of bluish shale	6
Not exposed (shale?)	70
Shale, poorly exposed; contains at least one bed of carbonaceous shale 2± feet thick	12
Shale, bluish gray, iron stained	28
Shale, brown, carbonaceous, with streaks of coal	5
Shale, light gray	3
Shale, carbonaceous, with streaks of coal	12
Shale, light gray, iron stained; bed of carbonaceous shale 1 foot thick near middle	85
Sandstone, yellowish, concretionary	7
Shale, brownish, carbonaceous, with streaks of coal	2
Shale, light gray, with yellowish concretionary layers	15
Shale (?); exposures poor but apparently show alternating thin layers of clay shale and carbonaceous shale; fairly definite 10-inch bed of brown carbonaceous shale near base	25
Shale, light gray, iron stained	20
Shale, brown, carbonaceous, with streaks of coal	3
Not exposed (shale?)	20
Shale, light gray, iron stained, increasingly sandy toward base	100
Sandstone, gray, iron stained, massive, cross-bedded.	
	951

The coal beds in the Priest Valley syncline have been prospected at three places—in Coal Canyon, which is a tributary of Waltham Creek; in sec. 21, south of Priest Valley post office; and in sec. 17. The following notes regarding these prospects were obtained mainly from Mr. Thomas Hart, of Priest Valley.

The first prospecting was done about 20 years ago by Hart & Drabble on the north side of Coal Canyon, in sec. 22, T. 20 S., R. 12 E. They ran a 60-foot tunnel, known as the Drabble mine, in what they called the "small vein," a bed 3 or 4 feet thick in the upper part of the carbonaceous zone, which is rather sharply separated from the main part of the zone by gray sandstone. About 2 carloads of coal was taken out and hauled to the railroad. The mine was then sold to a Mr. Bush, of Hanford, who ran a crosscut, starting a few hundred feet below the Drabble tunnel. This crosscut was about 390 feet long in 1893 and had penetrated the following beds:[1]

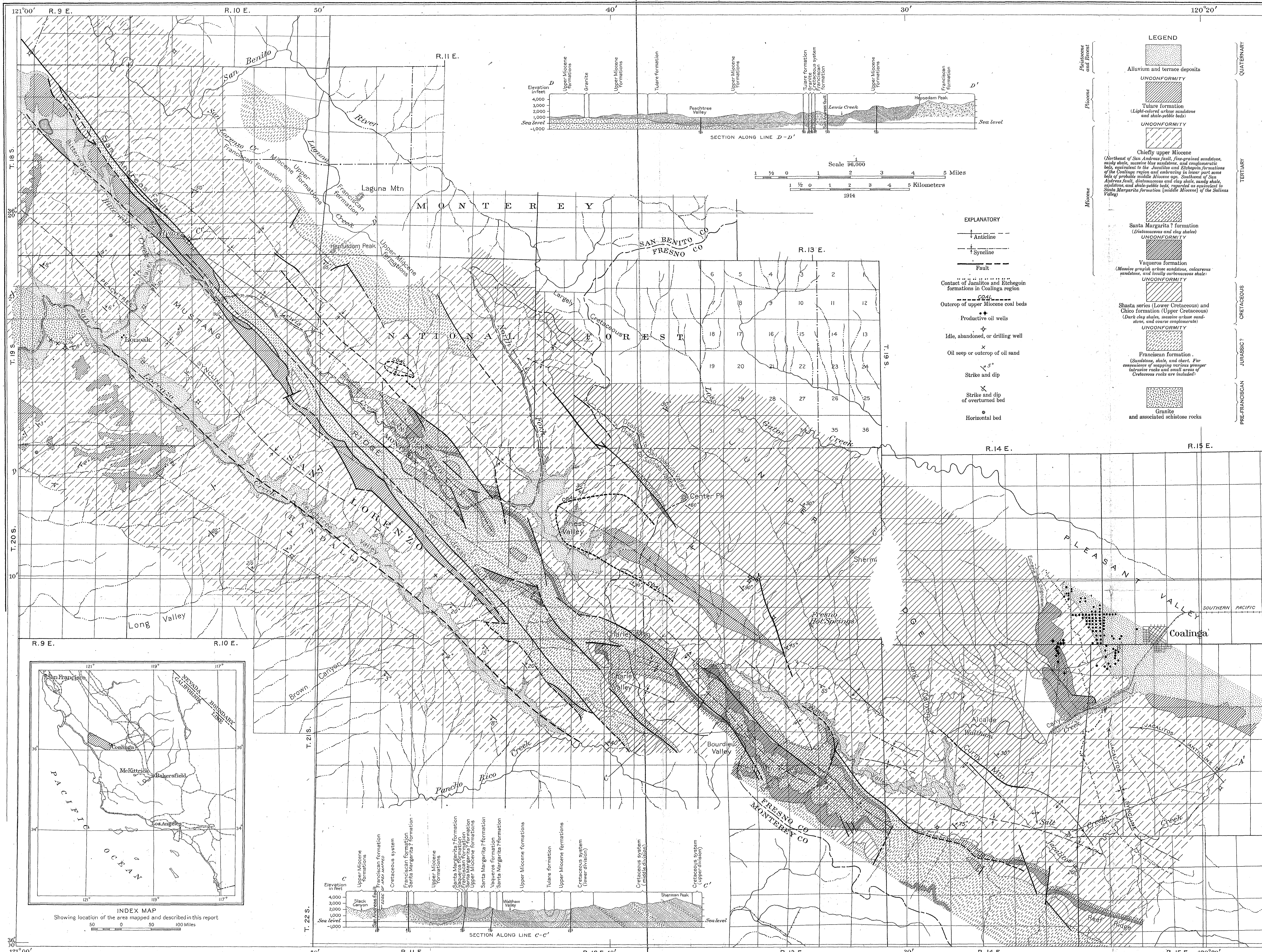
[1] California State Mining Bureau Thirteenth Rept. State Mineralogist, p. 53, 1896.

Beds penetrated in crosscut in Coal Canyon, Cal.

	Feet.
Soft gray sandstone	200
Light-blue compact clay	52
Coal bed No. 1, carbonaceous shale and seams of coal	4
Soft gray sandstone and shales	28
Gray compact argillaceous shale	7
Coal bed No. 2, coal and seams of shale	3
Sandy shales, passing into clay shales	96
	390

No more work was done until about 1907, when a company commonly known as the Monterey Coal Co., or the Pacific Coal & Clay Co., dug a 115-foot slope and a 35-foot tunnel in the ravine west of the old Bush and Drabble prospects. South of Priest Valley post office, in the NE. ¼ sec. 21, the same company dug a 60-foot slope and a 115-foot shaft, with 75 feet of drift at the bottom. In sec. 17, west of the post office, small pits have been dug along the outcrop of the coal. According to Mr. Hart, the coal weathers down rapidly into small platy fragments.

In secs. 20 and 21, T. 19 S., R. 11 E., about 4 miles southeast of Hepsedam, carbonaceous shale and thin coaly beds underlie an area of a little over half a square mile in a small syncline. These beds occur a few feet below the fossiliferous sandstone filled with *Pecten wattsi* that occurs above the coal in Priest Valley. A tunnel, which, according to Mr. Hart, is about 600 feet long, dug by the Pacific Coal & Clay Co., starts in beds that lie stratigraphically below the main carbonaceous beds but probably crosscuts them. At the time of visit this tunnel was not open and no coal was seen in the dump.



NOTE.—The area mapped as Santa Margarita? in secs. 2, 3, and 11, T. 20 S., R. 12 E., west of Center Peak, should have been shown as Franciscan.

Base from Priest Valley and Coalinga topographic sheets
U. S. Geological Survey

GEOLOGIC MAP OF THE WALTHAM, PRIEST, BITTERWATER, AND PEACHTREE VALLEYS, IN CENTRAL CALIFORNIA

Geology by Robert W. Pack and Walter A. English