DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 357

PRELIMINARY REPORT

ON THE

COALINGA OIL DISTRICT

FRESNO AND KINGS COUNTIES

CALIFORNIA

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1908

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PRELIMINARY REPORT ON THE GEOLOGY AND OIL RESOURCES OF THE COALINGA DISTRICT, FRESNO AND KINGS COUNTIES, CAL.

By Ralph Arnold and Robert Anderson.

INTRODUCTION.

General features of the district.—The Coalinga district is a strip of land about 50 miles in length by 15 miles in width lying along the northeastern base of the Diablo Range in western Fresno and Kings counties, Cal. The region is accessible by rail from the main lines of both the Southern Pacific and the Atchison, Topeka and Santa Fe railroads by a branch line running westward from Goshen to the town of Coalinga. The proved productive territory includes a band 13 miles long by 3 miles wide, lying at the northern end, and a narrow strip along the southwestern boundary. The oil originated in the organic Tejon (Eocene) shales and is accumulated in interbedded sands of the same formation and also in sands of the Vaqueros (lower Miocene), Santa Margarita (upper middle Miocene), and Jacalitos (upper Miocene) formations, the Vaqueros being the principal producer. The wells range in depth from 600 to over 3,300 feet, and penetrate from 20 to more than 200 feet of productive sands. The product varies from a black oil of 14° or 15° Baumé to a greenish oil of 35° Baumé or better. The yields range from 3 or 4 barrels a day for individual wells in the Oil City field to as much as 3,000 barrels a day for the deeper holes in the Eastside field. The total production of the district in 1906 was 7,991,039 barrels; in 1907 it was 8,871,723 barrels, and in 1908 it will probably exceed 12,000,000 barrels. According to the figures for 1907 the district ranks third in production among the oil-producing districts of the State.

Plan of the present report.—During the last half of 1901 and the first half of 1902 George H. Eldridge, of the United States Geological Survey, made more or less detailed examinations of the various California oil districts, with the expectation of preparing a monograph on the oil resources of the State. On his return from field work he wrote a brief résumé of the results obtained, and this was published in "Contributions to Economic Geology for 1902."[a] Later he began the preparation of detailed reports on each field, but his lamented death in June, 1905, cut short this work. In the fall of 1905 the senior author of this report was instructed to complete the work begun by Mr. Eldridge, and by the middle of 1907 detailed reports on all of the oil districts in the counties bordering the coast had been made ready for the press.[b]

The summer and fall of 1907 were spent by the writers in making a detailed geologic investigation of the Coalinga field proper and of the territory south of it as far as the Kings County-Kern County line near Dudley. In order to make the results of this investigation available as soon as possible, it has been deemed expedient to prepare the following preliminary report. This will be followed later by a bulletin containing more detailed descriptions of the conditions, more complete maps, sections, and other illustrations, and chemical analyses and calorific tests of a large number of the oils. The location of the Coalinga district and the other oil fields of southern California are shown in fig. 1.

For the benefit of those using this and other geologic reports on the California oil fields, it must be stated that these publications are intended to be as thoroughly scientific discussions as possible, and that they assume on the part of the reader a general knowledge of the fundamental facts and conceptions on which any searching study of the composition, mineral deposits, and history of the earth must be based. The reports may be criticised as being too technical and as not easily comprehensible by the ordinary reader, but the treatment adopted is the only one possible, because the thorough discussion of the subject involves a certain amount of technical knowledge and the use of exact terms. Explanatory discussions have been inserted wherever it seemed possible to do so without making the reports too bulky or diminishing their scientific value. For explanations of the principles of geology or the meaning of terms the reader is referred to any one of the numerous text-books of geology.[c]

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[a] Eldridge, G. H., The petroleum fields of California: Contributions to economic geology, 1902: Bull. U. S. Geol. Survey No. 213, 1903, pp. 306–321. (The part relating particularly to the Coalinga district is on pages 306–308.)

[b] Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: Bull. U. S. Geol. Survey No. 309, 1907.

Arnold, Ralph, and Anderson, Robert, Preliminary report on the Santa Maria oil district, Santa Barbara County, Cal.: Bull. U. S. Geol. Survey No. 317, 1907.

Arnold, Ralph, Geology and oil resources of the Summerland district, Santa Barbara County, Cal.: Bull. U. S. Geol. Survey No. 321, 1907.

Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Cal.: Bull. U. S. Geol. Survey No. 322, 1908.

[c] Any of the following, besides various others, will be found useful: Dana, Text-book of Geology; Le Conte, Elements of Geology; Chamberlin and Salisbury, Geology (3 parts); Geikie, Text-book of Geology.

Acknowledgments.—The writers wish to acknowledge their indebtedness to the late George H. Eldridge for notes collected by him during his examination of the field. Acknowledgment is also due to other previous workers in the field, among whom are W. L. Watts, Frank M. Anderson, John H. Means, and H. R. Johnson.

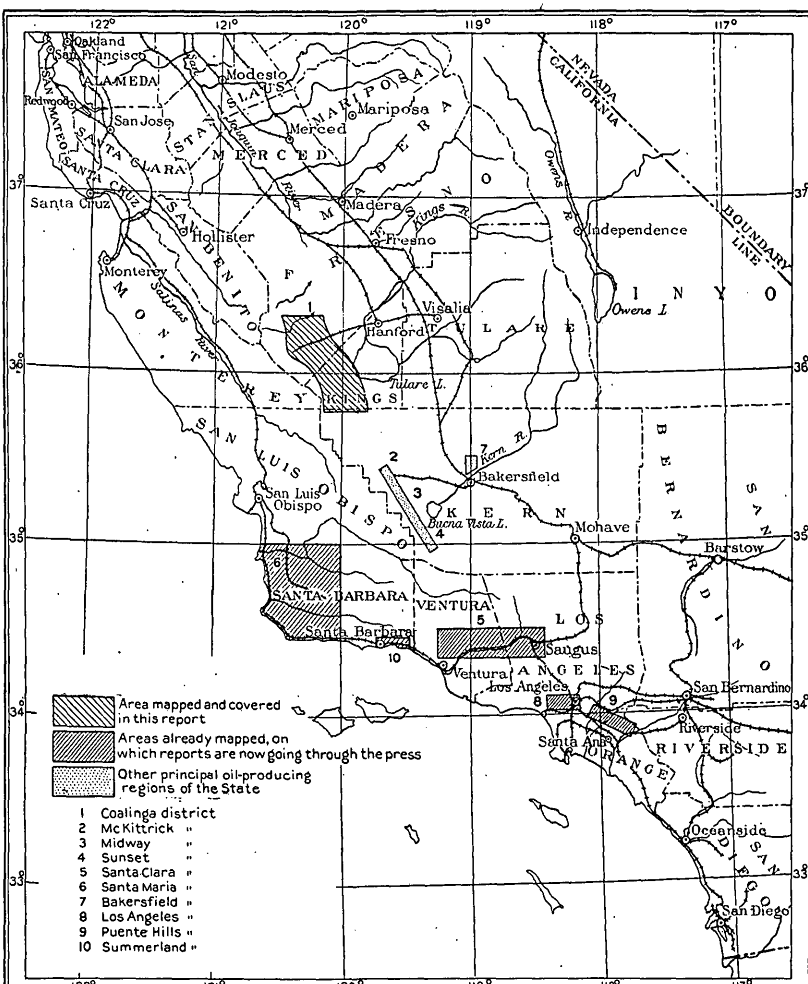

FIG. 1.—Index map of a part of southern California, showing location of the Coalinga oil field and of the other productive oil fields of the State.

The value and accuracy of a report like the present one, including as it does a discussion of the geology of developed territory, depends largely upon the amount and accuracy of the well data available for use in its preparation. Certain facts may be gleaned from a critical examination of the surface outcrops in any field, and many helpful conclusions may be deduced from a study of the facts thus obtained. A comparison of the conditions met with in a given territory with those in other better known fields may also be of great assistance, but for furnishing specific information regarding the occurrence of the oil in any particular area there is just one instrument, and that is the drill.

From the drilling of wells in the Coalinga field during the last ten years a large body of useful data concerning the underground conditions has been accumulated, and whatever accuracy and value there is in the underground map and in the statements concerning the geology of the wells in this report is due almost entirely to the generosity of the operators in this field in supplying the information. The writers therefore wish to acknowledge their indebtedness to the officers, managers, and other operators of the different oil companies for their hearty cooperation and support. Thanks are due more particularly to Messrs. Jas. H. Pierce, W. W. Orcutt, S. A. Guiberson, jr., R. W. Dallas, A. and H. Kreyenhagen, A. M. Anderson, H. G. Anderson, J. M. Atwell, Charles Babtie, Gordon M. Baker, R. C. Baker, Balfour Guthrie & Co., Orlando Barton, H. J. Bender, Scott Blair, S. R. Bowen, F. S. Brack, H. H. Brix, C. A. Canfield, Frank Cleary, H. R. Crozier, F. P. Dagany, P. B. Daubenspeck, D. M. De Long, J. F. Ecbert, Andrew Ferguson, A. D. Ferguson, W. S. Fisher, A. D. Fram, Charles Fredeman, W. M. Graham, W. A. Gray, W. A. Greer, L. P. Guiberson, H. D. Guthrey, S. H. Hain, H. H. Hart, H. Henshaw, W. A. Hersey, Paul Huntsch, W. A. Irwin, W. H. Kerr, W. P. Kerr, J. E. Kibele, Besley Lafever, J. L. Lennon, M. E. Lombardi, E. W. Mason, W. G. McCutcheon, W. O. Miles, J. H. Miller, S. E. Mills, R. B. Moran, T. A. O'Donnell, P. F. Page, R. S. Peeler, Z. L. Phelps, J. H. Raney, Charles V. Reynolds, George D. Roberts, C. N. Root, Guy H. Salisbury, George Schwinn, Max Shaffrath, R. E. Shore, R. H. Smith, H. F. Stranahan, R. E. Thompson, T. H. Turner, J. Waley, J. L. D. Walp, Alex Wark, J. H. Webb, M. L. Woy, J. B. Wrenn, John M. Wright, and many others who have contributed in one way or another to the value of the report.

The writers also wish to express their gratitude to R. B. Marshall, geographer in charge, and to E. P. Davis, topographer, for favors rendered during the course of the field season, when the topographic and geologic work were going on simultaneously.

Advantage of cooperation among operators.—The outlook will continue to be bright for the development at Coalinga of one of the greatest fields in California if each and every operator will conserve to the utmost the wonderful supply of oil stored within the boundaries of the district, and by wise management aid in keeping it available. The amount of available oil in the territory covered by the underground-contour map (Pl. II, in pocket) is estimated at 2,825,000,000 barrels. Contrary to the belief of some people, the underground resources of the earth are not inexhaustible; when the oil in any field is once gone it will not be replaced for many centuries, if ever. It may be true that the processes of oil formation and migration are constantly taking place in some localities, but such processes are so exceedingly slow, if measured in years, that for practical purposes they may be considered as having ceased altogether.

Fortunately the Coalinga field has had little of the serious trouble with water that is ruining certain parts of some of the other fields of California. This lack of trouble is probably due largely to the little disturbed condition and uniformity of the oil formations over most of the territory. But trouble from water is beginning to show its effects in certain parts of the field, and, through accident or carelessness, some wells not yet abandoned are believed to be letting water into sands that are productive in not far-distant wells. In order to avoid the dangers incident to faulty drilling and handling of wells, the operators should meet and exchange information about the underground geology. It seems shortsighted for one operator to withhold from his neighbor his logs and other information about underground conditions, when this very withholding may be the cause of his neighbor's flooding a large area through lack of proper knowledge in shutting off the water. Furthermore, it is hoped that those in legislative authority will recognize the needs of the petroleum interests in California, and, as has been done in other States, provide laws protecting the producers from negligent, shortsighted, or criminally careless operators.

GEOGRAPHY AND TOPOGRAPHY.

LOCATION.

The region mapped and referred to in this report as the Coalinga district is situated in the southern part of Fresno County and the western part of Kings County, Cal., and is bounded on the south by the Kern County line. It forms a long strip of territory extending from 119° 50′ west longitude and 35° 47′ north latitude at its southeast corner to 120° 37′ west longitude and 36° 20′ north latitude at its northwest corner, along the foot of the Diablo Range. This is the easternmost member of the Coast ranges on the border of the San Joaquin Valley of California. The district as mapped is roughly 50 miles long and 15 miles wide and includes about 700 square miles. It covers the foothill belt along the valley and extends back into the high hills to the summits of the first surrounding mountain ridges, its northwest and southwest corners reaching to the crest of the Diablo Range.

The developed oil territory commonly referred to as the Coalinga field is in the northern part of the district, in the foothill region around Pleasant Valley, where the town of Coalinga is situated. This is the only important settlement in the district or in a large surrounding region, the country being very sparsely inhabited. A railroad line connects Coalinga with the main lines of the Southern Pacific and the Atchison, Topeka and Santa Fe railroads in the San Joaquin Valley, and wagon roads enter the district at several points from the valley on the east. Roads cross the Diablo Range from the west by four routes, (1) over the Benito Pass at the head of Los Gatos Creek, (2) over the divide between Priest Valley and the head of Waltham Creek, (3) across the range between Stone Canyon and Waltham Creek, and (4) over Cottonwood Pass. The first enters the Coalinga district along Los Gatos Creek, the second and third along Waltham Creek, and the fourth through McLure Valley.

DEFINITIONS OF PLACE NAMES.

It is important that the names of the various places and features in the Coalinga district used in this report should be clearly defined before the topographic and geologic discussion is begun. The region is one in which little detailed investigation has been made, and most of the natural features are unnamed, while to many others names are indefinitely applied. The following definitions of names that have been newly applied and of names whose application has been made more definite have been submitted to the United States Geographic Board and have been approved and made permanent by that body. Most of these names appear on the map (Pl. I).

Coalinga district.—The application of this name to the whole region included in the map has been discussed in the preceding paragraphs.

Coalinga field.—The term field has been adopted as representing a subdivision of a district, and the name Coalinga field is used in this report in its accepted sense as meaning the region of the developed oil field in the northern portion of the territory mapped, round about the valley (Pleasant Valley) in which Coalinga is situated. This region is in turn subdivided into the Eastside, Westside, and Oil City fields, which are well known and will be defined later (pp. 74–107).

Kreyenhagen field.—Similarly the region of the hills west of Kettleman Plain is referred to as the Kreyenhagen field.

Kettleman Hills field.—The possible future oil field east of the Kettleman Plain will be referred to as the Kettleman Hills field.

Diablo Range.—The southern limit of the Diablo Range has been fixed at Antelope Valley in northwestern Kern County. Heretofore the name has been used indefinitely for part or all of the easternmost members of the Coast Range extending southeastward from the Carquinez Straits. Antelope Valley is fixed as the southern limit of the range because the mountains there sink into low spurs, and the continuation of the mountain belt beyond is a markedly individual range that is en échelon with Avenal Ridge, between Antelope and McLure valleys, which is the southernmost spur of the Diablo Range. The United States Geographic Board has determined that the correct name is Diablo Range, instead of Mount Diablo, Monte Diablo, or Sierra del Monte Diablo.

Temblor Range.—Southeast of Antelope Valley a range of distinct topographic and structural individuality forms the divide between the San Joaquin Valley on the northeast and the basin of San Juan Creek and the Carrizo Plain on the southwest. It extends from Cholame Creek on the north to about latitude 35°, where it merges with the high mountain mass around Mount Pinos called the Tejon Mountains. To this range the name Temblor is here applied. This name, which is Spanish for earthquake, is particularly suited to the range for two reasons. First, because the great California fault line, along which earthquakes have repeatedly originated, follows the range from one end to the other, being in the very heart of it throughout its northern part. A pronounced scarp resulting from the movement in 1868 can still be traced for much of the distance along this line. Second, because the well-known old Temblor ranch, west of McKittrick, is situated on its flanks.

Joaquin Ridge.—A very prominent structural ridge, here named Joaquin Ridge, runs east-southeast from the high mountains south of San Carlos Peak to the San Joaquin Valley north of Coalinga, forming the divide between Los Gatos Creek on the south and tributaries of Salt Creek and Cantua Creek that run northeastward to the San Joaquin Valley. The ridge heads at a mountain almost 5,000 feet high, situated in the southeastern portion of T. 18 S., R. 12 E., in the northeast corner of the area mapped, on the divide between the tributaries of Los Gatos Creek and San Benito River. Its summit is serrated with picturesque rocks, one striking group of which is locally known as the Joaquin Rocks. The oil field north of Coalinga lies on the nose of this ridge.

Anticline Ridge.—Southeast of a depression in the Joaquin Ridge in the southern part of sec. 34, T. 19 S., R. 15 E., a low broad line of hills extends about 6 miles to the railroad line in the gap formed by Los Gatos Creek. This ridge is formed by a perfect anticlinal nose and is therefore referred to as Anticline Ridge.

Juniper Ridge.—A corresponding and approximately parallel ridge runs south of Los Gatos Creek from the divide between that stream and Lewis Creek as far as the canyon of Waltham Creek (Alcalde Canyon). It is a high, rugged ridge separating the important Waltham Valley depression on the southwest from the Los Gatos Creek depression on the northeast and from the low hills between Los Gatos and Waltham creeks (Alcalde Hills) on the east. It is cut abruptly by Waltham Creek, south of which it is continued for about 2 miles in the isolated ridge known as Curry Mountain. It is here called Juniper Ridge owing to its characteristic vegetation.

Avenal Ridge.—The name Avenal Ridge is here applied to the mountains separating Avenal Creek and McLure Valley from the Cholame and Antelope valleys. It is the southernmost of the spurs of the Diablo Range. The name, which means a field of oats, is appropriate because the hills forming the ridge are rounded and grass grown.

Reef Ridge.—A prominent escarpment faces the low hills that border the Kettleman Plain, running southeastward from the southern fork of Jacalitos Creek (Jasper Canyon) as far as Little Tar Canyon, north of Dudley. This is formed by the prominent lower Miocene fossiliferous strata termed the "Reef beds," which dip at a high angle and, owing to their resistance to erosion, rise high above the softer sand hills on the northeast. This escarpment forms the northeastern flank of a ridge to which the name Reef Ridge is here applied. The name is expressive of its prominent topographic character.

Alcalde Hills.—The foothills between Los Gatos and Waltham creeks, east of Juniper Ridge, northwest of Alcalde and west of Coalinga are here called the Alcalde Hills.

Jacalitos Hills.—The foothills between Waltham and Jacalitos creeks are here called the Jacalitos Hills. Xacalli is an Aztec word adopted by the Mexicans, meaning Indian hut or wigwam, and Jacalitos means the little wigwams.

Kreyenhagen Hills.—The foothills southeast of Jacalitos Creek between Reef Ridge and Kettleman Plain may be named Kreyenhagen Hills. The name is that of three families owning large tracts of land there. They are early settlers and practically the only inhabitants, and the region is generally known as the Kreyenhagen country or Kreyenhagen's. Kreyenhagen field is the name used in this report for the oil field of the vicinity.

Pyramid Hills.—A long narrow line of hills borders the eastern side of McLure Valley, extending from Little Tar Canyon about 3 miles north of Dudley to the gap (Dagany Gap) where the Avenal flows out of the valley about 4 miles south of Dudley; south of this gap they continue into the Devils Den region. They form a ridge capped by a succession of conical hills, which when viewed from the east appear like isolated pyramids, and are therefore here called the Pyramid Hills.

Tent Hills.—A somewhat similar line of hills of peculiar topographic and geologic structure extends along the Avenal at the northeastern foot of the high ridge (Avenal Ridge) west of McLure Valley. They begin about 4 miles west of Dudley and run 3½ miles northwest, being separated from Avenal Ridge by a marked depression. Owing to the resemblance of the individual hills to tents they are here called the Tent Hills.

Guijarral Hills.—Immediately southeast of Anticline Ridge, on the opposite side of the railroad, is a small low group of gravelly hills referred to in the text as the Guijarral Hills. The word is Spanish and means a heap of pebbles or a place abounding in pebbles.

Dagany Gap.—The name Dagany Gap is used for the gap at the lower end of the McLure Valley south of Dudley. It is named from an old settler of that region.

Avenal Gap.—The Kettleman Hills are cut at latitude 35° 50′ by a completely graded stream channel now followed by Avenal Creek. It will be referred to as Avenal Gap.

Polvadero Gap.—At their northern end the Kettleman Hills are separated from the Guijarral Hills by a gap through which flow Zapato and Canoas creeks. It is called Polvadero Gap because it is subject to dust storms. Certain of the early land maps have it Pulvero, but this is not correct.

Pleasant Valley.—At least a portion of the valley at the mouth of Los Gatos Creek has been known as Pleasant Valley, the usage not being definite. The name may well be applied to the whole basin in which Coalinga is situated.

Waltham Valley and Creek and Alcalde Canyon.—The creek at the mouth of which Alcalde is situated is variously known as Wartham, Warthan, Waltham, and Alcalde. The United States Geographic Board has decided that Waltham is the correct name. This stream heads in a broad structural valley having no relationship in geologic character with the canyon through which it flows lower down. The name Waltham Valley, already in use for this upper valley, should be restricted definitely to it and not applied to the lower canyon, which it seems advisable to distinguish under the name Alcalde Canyon, thus preserving a name which is already understood as referring only to the lower part. This name is therefore applied to the canyon extending from the edge of Waltham Valley, where the stream cuts between Juniper Ridge and Curry Mountain, to Pleasant Valley. The stream itself bears the same name throughout.

McLure Valley.—The valley in which Dudley is situated has long been known as McLure Valley, after an early settler, now dead. According to old inhabitants this is the original and proper name. It is widely known also as Sunflower Valley, by reason of the abundant growth within it of wild sunflowers. The United States Geographic Board has decided that the former is the correct name.

Kettleman Hills and Plain.—The United States Geographic Board has decided that the name applied to these features should be written with an "e" and should not be spelled Kittleman.

Various creeks and canyons.—The United States Geographic Board has considered the various usages in regard to the names of the creeks in the Coalinga district, and the results of its decisions appear on the map (Pl. I, in pocket).

For convenience of reference the authors have applied names to several canyons in the district. The one which runs north and south 7 to 10 miles due north of Coalinga, and which is followed by the road to Oil City, is named Oil Canyon. The one in the Alcalde Hills which runs southeastward across sections 2, 11, 12, and 13, T. 21 S., R. 14 E., and which throughout its course across sections 2, 11, and 12 is practically coincident with an anticline, is called Anticline Canyon.

The application of the name Alcalde Canyon has been shown above. The southern fork of Jacalitos Creek may be appropriately named Jasper Creek from the picturesque and brilliant colored buttes of jasper that surround its upper portion, and the name Jasper Canyon is therefore applied to the gorge cut by this stream across the northwest end of Reef Ridge. The sharp canyon cut through Reef Ridge by Zapato Creek is called Zapato Canyon, and the similar one formed through Reef Ridge by the southern fork of Zapato Creek 2 miles farther east may be named Sulphur Spring Canyon, from the abundance of sulphur water that issues in it. The similar canyon at the head of Canoas Creek is called Canoas Canyon. The names Big Tar Canyon and Little Tar Canyon are in common use for the features to which these names are applied on the map.

Laval grade.—The Laval grade is a name locally known for the road leading northeastward up a branch of Oil Canyon, starting in that canyon on the eastern side of the NW. $\frac{1}{4}$ sec. 29, and crossing the ridge at the head of this branch canyon in the center of the NW. $\frac{1}{4}$ sec. 21, T. 19 S., R. 15 E.

GENERAL TOPOGRAPHIC FEATURES.

The Coalinga district owes its broader topographic features to its position along the border between the Coast Range and the San Joaquin Valley. It is largely a region of foothills that rise on the west into the mountains and merge on the east with the wide level plain. The foothills form several groups around the base of spurs descending southeastward from the Diablo Range, the groups being separated from each other by reentrant valleys that open out to the San Joaquin Valley.

The Diablo Range in this latitude is a rugged mountain group made up of various component members, some of which, owing to a complication of structures, run at angles oblique to the main trend of the range northwest and southeast. The crest of the range has a general altitude varying between 2,500 and 5,000 feet, and declines in height from the region northwest of the Coalinga district toward the region southwest of it, where it has been assumed as coming to a stop and giving place on the southwest to the Temblor Range. Portions of the watershed appear upon the map (Pl. I) at only two points, viz, in the northwest corner, which is marked by a peak nearly 5,000 feet high that stands at the head of Joaquin Ridge; and in the southwest corner, where the much lower Avenal Ridge, the southernmost spur of the range, appears. In the intermediate region the ridges that are represented on the edge of the map are in general separated from the main divide of the range by a region of lower relief determined by the presence of transverse structural valleys, of which Waltham Valley is the principal example. The general topographic development is youthful, but there is evidence in certain localities of different stages of development up to advanced youth. A feature of the relief of the whole region is the topographic reflection of the geologic structure, a feature that is especially pronounced in the foothills belt, with which this report particularly deals.

A peculiar feature of the Diablo Range is the occurrence along its eastern flanks of many spurs running out toward the southeast, and of reentrant valleys between these spurs. These ridges and valleys have an orientation slightly more to the east and west than that of the whole range, which trends in general about N. 36° to 40° W. and S. 35° to 40° E. They are primarily due to structural causes and not to erosion. The main salients of the Diablo Range that project toward the San Joaquin Valley in the Coalinga district are Joaquin Ridge and the Kettleman Hills, Juniper Ridge and Curry Mountain, Reef Ridge, the high hills northwest of McLure Valley between the drainage of Big Tar Canyon and Avenal Creek, and Avenal Ridge. These and the valleys or depressions separating them are the topographic expression of structural features running transverse to the main trend of the Diablo Range and are en échelon with each other.

Joaquin Ridge is anticlinal and exposes on its lower flanks the oil-bearing formations, thus determining the position of the oil field north of Coalinga. The ridge is structurally continued by the Kettleman Hills, which form a prominent isolated group rising over 1,000 feet above the San Joaquin Valley. The spur formed by Joaquin Ridge and the Kettleman Hills is separated from the rest of the district by the synclinal and faulted depression of White and Los Gatos creeks and the synclinal Pleasant Valley and Kettleman Plain. The two latter form a continuous, almost level, graded plain, opening only locally into the San Joaquin Valley through narrow gaps formed by graded stream channels.

Juniper Ridge and Curry Mountain, southeast of the Los Gatos Creek and Pleasant Valley depression, form a continuous structural feature probably due to faulting on the southwest side. In the southeastern portion of this spur it presents a steep scarp on the southwest bounding Waltham Valley, and on the northeast a gradual monoclinal slope into the Alcalde Hills. The end of Curry Mountain drops abruptly into a depressed area of low rolling hills (the Jacalitos Hills) that is the continuation southeastward of the Waltham Valley depression. Beyond this area a prominent salient springs up along Jacalitos Creek and extends southeastward as a high divide between the belt of lower relief, in which Jacalitos, Zapato, Canoas, and Big Tar creeks head, and the foothills bordering the Kettleman Plain. This divide is Reef Ridge, and all the streams named, as well as their forks, cut deep gorges through it. The ridge has a general monoclinal structure, the component strata dipping steeply northeastward into the foothills. The ridge is due, in large part at least, to the resistant qualities of the Vaqueros and Tejon strata forming its crest. At its southeastern extremity it gives place to the minor ridge of the Pyramid Hills, which is en échelon with it.

The next important salient enters the area shown on the map at a point south of the head of Big Tar Canyon and the Castle Mountain fault zone. It is a high and prominent group of hills forming the eastward continuation and the end of the precipitous ridge of Castle Mountain. Reef Ridge and the last-mentioned hills are separated from the next salient to the south by the wide plain of McLure Valley and by the valley of Avenal Creek. This depression is comparable in structure and size with Pleasant Valley. Southwest of McLure Valley rises Avenal Ridge, the main divide of the Diablo Range. It is formed by an important closely folded anticline that plunges steeply southeastward and brings the range to an end. Still farther southwest, on the opposite flank of Avenal Ridge, extends the large Antelope Valley, which is of the same peculiar structural type as the valleys already mentioned.

The foothills that swing around the bases of these spurs of the Diablo Range form a rolling surface that descends gradually to the surrounding plains. They owe their form chiefly to three causes: (1) The general reflection, on the surface, of the folds to which their uplift is due; (2) erosion along lines directed down the slope toward the valleys, at right angles to the structural lines, as a result of which a series of lateral ridges is formed; and (3) erosion along structural lines, particularly along bedding planes and lines of contact, as a result of which parallel longitudinal ridges and valleys and rows of hills are formed, and the lateral ridges deformed or dissected into hills. The succession of longitudinal ridges and intervening symmetrical troughs, to which the name Canoas, meaning canoes, probably refers, is a particularly striking feature of the Jacalitos and Kreyenhagen hills. Further detailed sculpturing is due to erosional wash along small channels tributary and at right angles or oblique to the streams determined by these two main factors. The soft formations of which the hills are largely composed lend themselves to minute, rapid, and fairly uniform sculpturing, which gives the hills a wrinkled appearance, especially evident when the rays of the sun, falling obliquely, cause an intricate scattering of light and shade. A general similarity of elevations is characteristic of the foothill areas, which, as a rule, show comparatively slight relative relief.

The two most important streams of the district are Los Gatos and Waltham creeks, which drain considerable areas and flow through deep, structurally important, and, in their lower portion, nearly graded valleys. These streams join in Pleasant Valley and pass out to the San Joaquin Plain through a gap cut across the uplift of the Coalinga anticline. The deep sharp canyon cut by Waltham Creek through Juniper Ridge and Curry Mountain and thence eastward for over 3 miles to Alcalde is worthy of remark. Other important streams are Jacalitos, Zapato, and Avenal creeks, of which much the same can be said, except that the origin of the lower courses of the former two is not so much due to structure as is that of the others mentioned. All of these are antecedent to the latest structural movements and form sharp cuts across features that have been uplifted in their path during Quaternary time. Owing to the slight rainfall in this region and the prolonged drought in summer none of these streams carries much water, and they all become nearly dry during the dry season.

Tulare Lake borders the southeastern portion of the Coalinga district east of the Kettleman Hills. It is broad and shallow, occupying a portion of the almost level floor of the San Joaquin Valley. It is supplied with water by several rivers descending the Sierra Nevada and has no outlet. Owing to unusual precipitation during 1907 it extended its borders widely, reaching nearly to the base of the Kettleman Hills. During preceding years the lake had been drying up and had almost ceased to exist. Its border as shown on Pl. I, therefore, represents an abnormally extended position.

GEOLOGY.

GENERAL STATEMENT.

The eastern slope of the mountains bordering the San Joaquin Valley is formed by a great thickness of strata dipping toward the valley. The oldest rocks exposed appear in the axis of the mountain range at the base of the monocline, successively younger formations appearing eastward as the edge of the valley is approached. The different formations that may be recognized as units in this series, with the time divisions to which they correspond, are as follows, from the oldest to the youngest: Franciscan (Jurassic?), Knoxville (lower Cretaceous), Chico (upper Cretaceous), Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (upper middle Miocene), Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), Paso Robles (Pliocene and early Pleistocene), and late Quaternary alluvium and terrace deposits. These formations, with the exception of certain igneous and metamorphic rocks associated with the Franciscan, are of sedimentary origin, the sediments being marine, with the exception of most of the Paso Robles and later deposits. They indicate that the greater portion of the area included within the Coalinga district was beneath the sea during intervals occupying probably the major portion of the time from the Jurassic to the end of the Miocene. The latest movements of the land, which produced the features of topographic relief now to be seen, did not take place until within Quaternary time.

The first three of the above formations are of little importance in this district in connection with the occurrence of petroleum. The Tejon and Vaqueros are the principal reservoirs of the oil, and are therefore of prime importance. The Santa Margarita and Jacalitos are petroliferous only at their bases, and their upper beds, together with those of the Etchegoin, are the strata which overlie the oil sands and through which the wells are drilled, so that their relation, thickness, character, and structure have an important bearing on the problem of accessibility of the oil and are worthy of detailed study. The Paso Robles formation is of less direct importance in this connection, but is of aid in throwing light on the structure and the relations of the different formations.

STRATIGRAPHY.

FRANCISCAN FORMATION (JURASSIC?).

General description.—The central portion of the Diablo Range is occupied by an old and for the most part much-altered formation that is in every way similar to the well-known Franciscan formation of other parts of the State. It comprises the oldest rocks here exposed, as it antedates the Knoxville (Lower Cretaceous), but further than this little can be said regarding its age. It is usually considered Jurassic, but elsewhere there is no good fossil evidence of its age, and in this region none has been found.

The Franciscan is easily recognizable, as it is characterized by typical rocks and topography. The most characteristic feature of the areas occupied by the Franciscan is the serpentine, which is everywhere associated with it and which is here considered a part of it, although in reality intrusive in the sedimentary rocks, and therefore of later age. The original sedimentary rocks, which are sandstone, shale, and jasper, occur in detached areas and are greatly disturbed. They are intimately associated with glaucophane, actinolite, and other schists; serpentine, and other metamorphic rocks; and in one area shown on the map with soda-bearing hornblende syenite. In the portion of the Coast Range within and bordering the Coalinga district the metamorphic rocks of the Franciscan formation greatly predominate over the unaltered ones. In the small area of Franciscan sedimentary beds in the northwest corner of the district, the alternating beds of sandstone and shale closely resemble the strata in the lower portion of the Knoxville-Chico and are difficult to separate from them. The serpentine covers a much larger area and extends far beyond the limits shown on the map over a continuous stretch estimated as being at least 40 square miles. The Franciscan formation and associated rocks are considerably mineralized and contain deposits of cinnabar, asbestos, and the newly described gem mineral, benitoite.[a]

Importance with relation to petroleum.—The rocks of the Franciscan are not known to contain any petroleum. The formation is of different character from the formations in which the oil is found and has no direct relation to them. Even if it had once been a source of petroleum, the disturbance that it has undergone could have allowed little to remain.

KNOXVILLE-CHICO ROCKS (CRETACEOUS).

General description.—The next oldest rocks exposed in the Coalinga district comprise a thick series of strata of sandstone, shale, and conglomerate overlying with probable unconformity the Franciscan formation just described, and covering a wide belt for the most part west of the foothill region. They form the high hills north and south of Los Gatos and Waltham creeks and may be easily recognized by the dark, thin-bedded, compact shale and sandstone of the lower portion and the massive, drab, concretionary sandstone of the upper portion. These rocks are of Cretaceous age and comprise part or all of the two formations well known elsewhere on the west coast as Knoxville (lower Cretaceous) and Chico (upper Cretaceous). Owing to the lack of fossil or stratigraphic evidence in the Coalinga district sufficient to form the basis for a separation between these two formations, they are mapped and described together for the present.

The rocks, however, may be separated lithologically into three divisions. A marked distinction between the lower and upper portions has already been noted, but the thin-bedded shale and sandstone making up the lower portion is divided into two parts by a

[a] Louderback, G. D., Benitoite, a new California gem mineral; with chemical analyses by W. C. Blasdale: Bull. Dept. Geol. Univ. California, vol. 5, No. 9, July, 1907. pp. 149-153. Also, Arnold, Ralph, Notes on the occurrence of the recently described gem mineral benitoite: Science, new ser., vol. 27, No. 686, February 21, 1908, pp. 312-314.

conformably interbedded zone of coarser sediments and in places by several hundred feet of coarse massive conglomerate, as along Alcalde Canyon and on Juniper Ridge.

The beds above and below the conglomerate zone are of the same character, predominantly dark argillaceous shale in thin layers with partings of sandstone, but it is possible that the conglomerate zone represents an important stratigraphic separation. Chico (upper Cretaceous) fossils have been found north of White Creek and near Alcalde in the shale series at horizons higher than the conglomerate, and it is possible that the zone of coarsening in the sediments represents the base of the Chico. The beds below the conglomerate are at least 3,000 feet thick, and probably belong to the Knoxville (lower Cretaceous). Fossils of this age have been found in similar beds in the Devils Den region, not far south of the area mapped. The strata of the middle division, above the base of the conglomerate, have a thickness of at least 4,800 feet.

The uppermost of the three divisions is predominantly sandstone, and has a thickness of at least 3,500 feet. The sandstone is usually of a drab color, medium grained, and not very hard. It occurs in massive beds, often weathering cavernous, that stand out prominently and display the structure on the sides and tops of the ridges north of Los Gatos Creek and west of Coalinga. Rocks of this division may be easily recognized by these characteristic outcrops and by the numerous large, hard, reddish-brown concretions of which the sandstone is full and which weather out and remain in patches on the surface. The beds are in places so concretionary that the individual oval concretions lose their identity and the beds are composed throughout of hard brown rock like that forming the concretions. The prominent sandstone strata are separated by poorly exposed, softer beds of sand and light-colored shale. Locally the sandstone is conglomeratic. Thin seams of calcareous shale and sand are at some points interbedded with the softer beds. At the base of this division of the Knoxville-Chico rocks, the massive sandstone beds give place to thinner beds alternating with finer-grained sandstone and shale, and these grade over into the thin-bedded series described as the middle division. The transition takes place within a few hundred feet, and in places a fairly sharp line can be traced between the beds that are predominantly sandstone and those in which the thin layers of fine grain predominate. Fossils of Chico (upper Cretaceous) age occur at various localities in sandstone and conglomerate in the lower portion of this upper division; the upper portion has not furnished fossils and can be only doubtfully referred to the Chico formation. The upper part of the concretionary sandstone series may be either Chico or Tejon (Eocene), or a transition between these two formations. The division is, however, fairly homogeneous in character and seems to represent a separate stratigraphic unit, and it is therefore, for the time being at least, referred as a whole to the Chico formation; considered as such, it is strikingly distinct from the divisions below and from other formations in the district.

Importance with relation to petroleum.—The Knoxville-Chico strata are not petroleum bearing so far as known. It is possible that traces of oil may be found in them, but there is nothing to indicate that they contain it in quantity sufficient to be of economic importance. The beds underlie the Tejon (Eocene) formation, in which the petroleum of the Coalinga district is supposed to have originated, and below which no petroleum has been found.

TEJON FORMATION (EOCENE).

General description.—The beds of the Knoxville-Chico are overlain unconformably by beds belonging to the Tejon (Eocene) formation. This is a marine sedimentary formation, which was named from the locality near Fort Tejon in Kern County, where it occurs typically. It forms a belt along the western edge of the San Joaquin Valley and is exposed intermittently in the region between the type locality and the Coalinga district. No sharp line of demarcation is to be drawn between the Tejon and the underlying Chico in the northern part of the district, and in places there appears to be a gradation from the beds of the former into those of the latter, as if they had been formed during a continuous period of sedimentation.

The Tejon formation in the Coalinga district is made up entirely of sedimentary strata that dip toward the San Joaquin Valley in the monocline along the eastern flank of the mountains, and are exposed on the surface in a narrow discontinuous belt between the beds of Cretaceous which underlie them and those of the Miocene which overlie them. Broadly speaking, the Tejon formation here may be divided into a lower sandstone portion and an upper shale portion, but no sharp division can be made that will be applicable throughout the district under discussion. The most important and distinctive feature of the formation is the predominantly fine-grained nature of the beds toward the top as compared with those below. The Tejon comprises a thickness of from 1,400 to 2,300 feet where exposed most completely, the upper half of which is made up of thin beds of whitish and purplish, siliceous, argillaceous, and locally calcareous shale which is easily recognizable and which lends individuality to the formation. The lowermost few hundred feet are of variable sandy beds locally fossiliferous. The upper shale is very similar—especially in some places, as north of Coalinga—to the siliceous shale of the formation along Reef Ridge described later as the Santa Margarita, and the two must not be confused. Where the

Tejon formation is thick, the shale portion forms a greater proportion of the whole than does the sandstone, the middle beds being chiefly of fine grain. The middle beds differ from those at the top in being more argillaceous, of a darker color, less prominent, and more frequently interbedded with sandy beds.

There are three separate areas in which the Tejon is exposed, one in the oil field north of Pleasant Valley, another on the eastern border of the Alcalde Hills just west of Coalinga, and the third along Reef Ridge. Between the Alcalde Hills and Reef Ridge it is covered, as is the Cretaceous below, by the overlapping Miocene beds.

North of Pleasant Valley.—In the northern region the Tejon is typically exposed in the hills directly north of Coalinga in the vicinity of the camp called Oil City. Here it seems to be conformable with the Chico and to represent either continuous sedimentation between the Cretaceous and Eocene or else a period of tranquil conditions between the deposition of the two formations. The line of contact between them shown on the map represents the top of the hard, brown, concretionary beds, which are assumed to be the uppermost Cretaceous beds of this district. The Tejon (Eocene) beds are markedly unconformable with those of Miocene age above, which lie with a low dip upon the sharply folded and overturned shales characteristic of the upper part of the Tejon. The formation is here more completely exposed than elsewhere within the district and has a thickness of at least 2,300 feet. The uppermost beds for a few hundred feet down are chiefly of white, siliceous, hard and brittle, thinly bedded diatomaceous and foraminiferal shale. This shale grades below into softer, crumbly, very gypsiferous, thinly bedded clay shale and sandy shale of a purplish-brown color, which makes up the greater part of the formation. The shale is locally variable in color, assuming different yellowish and reddish tints as the result of staining by petroleum. It contains an abundance of crystallized gypsum with minor amounts of alkaline mineral matter and sulphur along the intricate fracture planes. Numerous dikes of sandstone traverse the beds in various directions, and sand and sandstone of variable character are interbedded in lesser amounts with the shale in the middle of the formation. The lowermost 700 to 1,000 feet is made up chiefly of interbedded hard and soft sandstone that is variable in color, but is frequently yellowish. The bedding throughout the formation is usually thin and inconspicuous, and especially in the upper half is apt to be very irregular.

Southwest of Oil City the Miocene beds gradually lap more and more upon the Eocene, leaving less of it exposed. Owing to lack of exposures of the underlying rocks for 1 or 2 miles north of Los Gatos Creek, where it opens out to Pleasant Valley, and the structural complexity of that area, the lines of contact drawn there are theoretical and are at best only approximately correct.

South of Los Gatos Creek.—The outcrops of Tejon appear again south of Los Gatos Creek, in a belt along the base of the foothills facing Pleasant Valley. The formation is conformable with the Chico and the rocks near the contact are fairly well exposed. The line drawn at the top of the concretionary beds, which are supposed to be at the top of the Chico (upper Cretaceous), marks the base of some beds of light-yellow and white, soft, gypsiferous sand that are taken as the lowermost Tejon (Eocene) of this district. Within 100 feet above this contact occurs a bed of a calcareous sandstone locally greatly hardened and full of typical Tejon fossils. At the two coal mines northwest of Coalinga the yellow sand at the base of the formation is exceedingly gypsiferous and variable in character, and appears to be a shallow-water deposit. It contains seams of lignite and carbonized wood, which in former years have been mined. Above this sand, which has a thickness of about 200 feet, occur thin beds of light-colored, somewhat siliceous, hard shale, and soft, purplish-brown, gypsum-bearing argillaceous shale, composing the upper half of the formation. The latter beds are steeply tilted and fractured, and their truncated edges are overlain by Miocene beds with low dip. The unconformity is well exposed in the canyon of the San Joaquin Valley coal mine. At one place 4 miles northwest of Coalinga, within 500 to 600 feet above the base of the Tejon, there is exposed a bed of soft diatomaceous shale which probably represents part of the siliceous zone toward the top of the formation farther north, although it is not impossible that it occurs within the Miocene beds. Owing to the covering of soil on the undulating ground at the edge of the plain northwest of Coalinga the thickness and extent of this diatomaceous material, or of the formation as a whole, can not be determined. It may be said, however, that the shale portion of the formation has a thickness in this part of the field of at least 300 feet below the highest horizon that the unconformably overlying Miocene leaves exposed. The Miocene spreads more widely over the Tejon farther to the south until the strike of the latter carries it completely beneath the Miocene beds at a point about 3 miles west of Coalinga.

Reef Ridge.—Beds of Tejon age appear again on Reef Ridge, where the same broad lithologic characteristics may be noted, namely, a sandy, frequently yellowish lower portion, and a purplish shaly upper portion, although many minor differences are evident in the manner of occurrence north and south of the Miocene overlap. The Tejon beds of Reef Ridge, as compared with those in the northern locality, are in general more indurated and more regularly and steeply tilted. The sandstone is more massively and regularly bedded and coarser at the base, and the shale is of different character and more homogeneous. The formation rests on what is with little doubt a lower portion of the Cretaceous, probably unconformably. An angular unconformity between the Tejon and the Miocene beds above it on Reef Ridge was not plainly found as it was in the Coalinga field, but there is good reason to believe that an unconformable relation exists between the two formations here as well as farther north.

The Tejon of Reef Ridge is exposed typically in the gorges that cut this ridge between Zapato Canyon and Big Tar Canyon. It is made up of a basal zone of conglomerate ranging in thickness from a few feet to over 100 feet, of a succession of sandstone beds aggregating about 550 feet in thickness, and of an upper shale portion of which a thickness as high as 900 to 1,000 feet is in places exposed. The Tejon becomes thinner west of Zapato Canyon and is not known to outcrop in that direction west of Jasper Canyon. Toward the southeast the Tejon passes under the overlapping Santa Margarita (upper Miocene) near the extremity of Reef Ridge and disappears entirely. Only one small outcrop of it was found on the southwest side of McLure Valley. It was probably deposited over much of this region and later removed by erosion before the deposition of the Santa Margarita formation, which rests directly upon the Cretaceous beds. Rocks of Eocene age reappear still farther south in the Devils Den region and beyond.

The sandstone of the Tejon formation may be easily recognized by the prominent line of peaks that it forms along Reef Ridge a few hundred feet behind the abrupt frontal escarpment produced by the "Reef beds." It is for the most part homogeneous, yellowish-gray, medium-grained, oil-stained, massive sandstone, locally very hard, especially in the upper portion, but usually fairly soft. In places it is concretionary and becomes cavernous by weathering. A characteristic feature of it is that it supports a heavy growth of vegetation as compared with the shale above it. It attains its greatest development in the central portion of its extent and thins toward the two ends of Reef Ridge.

This sandstone contains typical Tejon (Eocene) invertebrate fossils which place it definitely in this formation and allow its correlation with the fossiliferous sandstone of the Tejon, already described from the Coalinga field. At its base it grades into the locally variable conglomerate zone before mentioned, which is taken as marking the base of the formation for the reason that it rests unconformably upon the dark Cretaceous shale in the region of Big Tar Canyon and the head of Garza Creek. Farther west, however, in the vicinity of Canoas and Sulphur Spring canyons, the coarse beds at this horizon rest with apparent conformity and intergradation upon a great thickness of beds of sandstone and soft sandy shale and carbonaceous clay shale that are unlike Cretaceous strata of other parts of the district. It is possible that this underlying terrane is part of the Tejon formation that is lacking elsewhere, but it is mapped for the present with the Knoxville-Chico (Cretaceous). No fossils have been found in it and sufficient work has not been done upon it to determine its relations.

The shale overlying the sandstone of the Tejon is less resistant to weathering and forms a belt of low topographic relief between the line of peaks formed by the lower sandstone and the sharp ridge of the Vaqueros (lower Miocene) "Reef beds." This belt is marked by few outcrops and is almost entirely bare of vegetation except grass and scattered small juniper and oak trees. The rocks of this zone are well exposed only in the canyons, where they form thin beds of purplish shale steeply tilted and considerably fractured and distorted. At the base the beds of this member are almost invariably poorly exposed, but they seem to be somewhat sandy through a thickness of about 200 feet, as if representing a transition from the sandstone of the lower member. Above this transition zone the beds are fine-grained argillaceous and siliceous shale, usually finely comminuted, of a peculiar dark purplish-brown color, and similar to some of the shale in the upper member of the formation north of Coalinga. Many of the cracks in the shale are lined with sulphur. Toward the top the shale becomes in places, as near and southeast of Big Tar Canyon, of a yellowish or whitish color, and both siliceous and calcareous, the latter variety containing innumerable foraminiferal remains. These varieties bring out still more strikingly the resemblance to the shale member north of Coalinga and leave little doubt that the same horizon is represented in both localities. The thickness of beds exposed between the sandstone member of the Tejon and the Miocene varies from place to place along Reef Ridge. The maximum thickness that has been found is in the neighborhood of Canoas Creek, where it is about 1,000 feet.

Age and relations of the shale of the Tejon formation.—No very characteristic fossils have been found, either in the northern or in the southern parts of the district, in the shale overlying the sandstone known to belong to the Tejon formation, and therefore its classification with the Tejon is not final. It is considered as a portion of the Tejon (Eocene) because it is in apparent continuity with the beds of that age, because it is found in association with those beds wherever they occur, because it underlies unconformably beds containing fossils of lowest Miocene age, and because it contains fossils that point to its Eocene age. It is not thought probable that it belongs in the Oligocene, because rocks of that age have not been recognized in the Coast Range south of the Santa Cruz Mountains. The unconformity between this shale and the lower Miocene is profound in the Coalinga field. On Reef Ridge it is not apparent along the contact, but the tilting of the shale beds is in general steeper and the disturbance greater than in the Miocene above. At the northwest end of Reef Ridge the Vaqueros (lower Miocene) overlaps and rests directly upon the dark shale of the lower portion of the Knoxville-Chico, proving for this portion of the district, as well as the northern portion, the existence of an important unconformity between the Tejon and the Vaqueros. The variable thickness of the shale of the Tejon formation exposed along Reef Ridge indicates an overlapping of the Miocene upon different horizons, and the fact that the light-colored calcareous and siliceous shales that are characteristic of the uppermost horizon in the Coalinga field are absent in most places along Reef Ridge, though present in others, is a further proof of the existence of such overlaps.

Importance with relation to petroleum.—The shale in the upper part of the Tejon is thought to be the source of the petroleum found in the Coalinga district. The sandstone both above and below it is saturated and stained with oil, and although the shale itself does not give evidence of containing much petroleum it shows the effects of being stained by it. Petroleum has not been found in this district except in beds associated with the Tejon, and where the Tejon is absent the beds of the other formations are dry. Along Reef Ridge the sandstone of the lower half of the formation is saturated with oil, in places through its whole thickness. The sand has a strong odor and when a fresh fracture surface is exposed it is found to be stained brown throughout. Included layers of shale are stained purple. All the wells that are drilled through the shale to this sandstone strike oil in it in small amounts. The great thickness of the sandstone through which the oil has permeated lessens the probability of its being found in large amounts locally. It is probable that this oil originated in the shale above and became absorbed in the sandstones above and below. The occurrence of oil in the overlying Miocene beds will be mentioned later.

It is believed that the shale in the upper part of the Tejon contains a large proportion of material of organic origin. The calcareous facies is composed in part of foraminiferal remains, and the hard siliceous beds are very similar to the altered varieties of diatomaceous and foraminiferal shale found in other formations in other parts of the State. In places in this district the shale is softer and less altered and is composed largely of diatom remains. It is probable that these small marine organisms have been the chief source of the oil.

In other parts of California the origin of the petroleum is ascribed to formations of similar peculiar character, although of different age, and it is a striking fact that all the conditions point to the diatomaceous or foraminiferal nature of the deposits as the determining factor in the original occurrence of petroleum rather than to the age or other characteristics of the formations.

THE POST-EOCENE FORMATIONS.

General statement.—The Miocene, Pliocene, and early Pleistocene periods are represented in the Coalinga district by a series of formations that form a group by themselves, distinct from the older formations. The first impression received on viewing the field is that the later Tertiary beds form one continuous succession, and it is therefore natural to take up first a brief review of the whole series before passing to the more detailed description of the different divisions of it, which on closer study are found to be separable from one another.

The Miocene epoch was occupied in the Coalinga district by fairly continuous marine conditions. There was rapid erosion of areas of considerable relief situated probably along the line of the present mountainous belt, and deposition of the eroded material in great thicknesses in changing and, for the most part, slowly subsiding submerged basins. The formations thus deposited underwent disturbances during these periods, and were finally affected as a whole after the close of the Tertiary by the land movements, to which the greater part of the disturbance at present visible in the beds is due. As a result of these processes the periods following the Eocene are here represented by a great series of sandstone and shale and conglomerate beds, all tilted at about the same angle, having usually similar characteristics and presenting an almost perfect appearance of conformity and intergradation. By means, however, of discontinuous fossil faunas, distinguishable lithologic groups, the absence in some places, as a result of overlap, of formations or zones known elsewhere, and the appearance of fragments of older formations within younger ones, several important breaks, which prove the intervention of periods of time during which land conditions existed over wide areas or locally, may be definitely made out. The important post-Eocene formations that represent the epochs of submergence of the land in the area now occupied by the Coalinga district are the Vaqueros (lower Miocene), the Santa Margarita (upper middle Miocene), the Jacalitos (early upper Miocene), and the Etchegoin (late upper Miocene). The formation following these, the Paso Robles (Pliocene and lower Pleistocene), is probably in large part of different origin, but is similar to the others in the general features of its appearance. These formations are all united into one series in the monocline dipping down the east flank of Joaquin Ridge in the northern part of the district and again in the monocline dipping away from Reef Ridge in the southern portion, but the character of the series is not entirely the same in the two regions.

The series in the north.—In the northern part of the district the base of the Miocene-Pliocene is formed of coarse and fine oil-impregnated sands unconformably overlying the whitish and purplish petroliferous Eocene (Tejon) shales, these sands being overlain by prominent sandstone beds, by a prominent zone of white siliceous shale, and by soft sand, up to the base of a zone of bluish and variegated clay and sand locally known as the "Big Blue." Up to this point the beds are fossiliferous, have a thickness of about 550 feet, and are mapped as Vaqueros (lower Miocene). The "Big Blue" has a thickness of about 300 feet and is unfossiliferous. It is overlain by a thickness of about 175 feet of coarse sand and sandstone beds full of immense oysters, barnacles (*Tamiosoma*), scallop shells (*Pecten*), and other fossils, which beds may be named the *Tamiosoma* zone. This is overlain by 400 to 500 feet of sand and gravel beds up to the base of a very prominent gravel zone full of petrified wood. The beds from the base of the "Big Blue" up to this point are mapped as the Santa Margarita (upper middle Miocene) formation. The fossil-wood and gravel zone forms the base of a succession of sand, sandstone, gravel, and clay beds extending up to the base of a prominent zone of bluish-gray sand beds, having near their base a rich fossil bed (the *Glycymeris* zone). The succession of beds up from the base of the gravel zone to this point has a thickness of about 1,600 feet, and is mapped as the Jacalitos formation (early upper Miocene). The fossil bed and bluish sands immediately overlying grade upward into sand and clay beds, the whole forming a thickness of about 1,700 feet, which is mapped as the Etchegoin formation (uppermost Miocene), and this finally is overlain by poorly exposed coarse gravel deposits, which are mapped as the Paso Robles formation (Pliocene-lower Pleistocene). The total thickness of the succession in the Coalinga field thus outlined is about 4,600 feet, exclusive of the Paso Robles formation, which can not be measured in this portion of the district.

The series in the south.—In the southern part of the district the basal portion of the Miocene-Pliocene consists of about 700 to 900 feet of steeply dipping hard sandstone and conglomerate beds, forming the face of Reef Ridge. These overlie with an important, though usually not apparent, unconformity the shale of the Tejon (Eocene), and are locally petroliferous. At the summit they grade into softer beds overlain by hard siliceous shale. Up to this shale the beds are fossiliferous, and are mapped as the Vaqueros sandstone. The overlying shales are hard and whitish, form a prominent zone varying up to 1,200 feet in thickness, and are mapped as Santa Margarita, although only tentatively referred to that formation. These shales are overlain by a great succession of beds of sandstone, shale, sand, clay, gravel, and conglomerate of many varieties, having a thickness, as measured in a section south of Big Tar Canyon, of at least 9,500 feet, and presenting no prominent line of constant variation which may be taken as a separation between distinct terranes. This succession is, however, divided on the map, on the basis of criteria to be discussed later (pp. 40–61), into three approximately equal divisions corresponding to the formations in the north, namely, the Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), and the Paso Robles (Pliocene–lower Pleistocene). The total thickness of the Miocene-Pliocene and the lower Pleistocene measurable in the above-mentioned single section is over 11,000 feet.

VAQUEROS SANDSTONE (LOWER MIOCENE).

General description.—The unconformity at the top of the Tejon (Eocene) marks an important lapse of time before the beginning of the Miocene epoch. In the early Miocene a sedimentary formation was deposited in the Coalinga district that is the correlative of the formation known as the Vaqueros sandstone in the region nearer the coast. The contemporaneity of these formations is shown by the fact that the fossil remains of mollusks characteristic of lower Miocene time exist in both.

The Vaqueros sandstone in the area under discussion forms an elongated belt east of the belt of Tejon in the hills bordering the San Joaquin Valley. It consists of hard and soft sandstone, shale, and conglomerate, varying from 550 feet in the Coalinga field to 900 feet in the Kreyenhagen field, and may be easily distinguished from all other formations by the protruding tendency of the hard sandstone, known as the "Reef beds," in its central portion. These beds outcrop prominently in the northern portion of the district, and again in the southern portion assume such prominence as to dominate the landscape on the bold face of Reef Ridge. They are much more resistant to erosion than the soft associated beds, and, dipping toward the valley on the northeast at an angle varying from 50° to 80°, they form the scarp and double row of pinnacles of Reef Ridge fronting the foothills on that side.

An important distinguishing feature of the Vaqueros is that the beds at its base are the chief oil sands of the Coalinga district. In many places they are saturated and discolored with petroleum. They rest upon the eroded surface of the shale of the Tejon throughout most of their extent, but overlap in the Alcalde and Jacalitos hills upon the Knoxville-Chico (Cretaceous) rocks, thus hiding the Tejon (Eocene) from view. Where such overlapping occurs, the basal beds lose their petroliferous character at a distance from the Tejon.

There are three different areas along the belt of outcropping Vaqueros which deserve separate description owing to the diversity of character assumed by the formation in them. One of these is in the oil field north of Coalinga, a second extends from a point in the Alcalde Hills west of Coalinga to Waltham Creek, and the third extends along Reef Ridge. The first two areas are separate. The second and third areas are shown on the map as discontinuous, but it is possible that a narrow belt of Vaqueros is exposed south of Waltham Creek, and that this connects with the belt on Reef Ridge.

North of Pleasant Valley.—In the hills north of Coalinga the formation includes all the beds overlying the Tejon at least as far up in the series as the base of the zone of fine grayish sand and clay locally well known as the "Big Blue," and possibly to the summit of this zone, which is at the base of the *Tamiosoma* zone. The "Big Blue" is not known to be fossiliferous and presents therefore no definite basis for correlating it, but it is mapped for the present as a portion of the overlying formation (the Santa Margarita) and the summit of the Vaqueros is placed at its base. The Vaqueros formation is thereby restricted to those beds which are known by their fossils to belong to it. Its thickness is about 550 feet.

The lowest bed of the formation is coarse, irregular, pebbly sand truncating the eroded edges of the Tejon formation. It is followed above by rough-bedded, hard and soft, both coarse and fine sandstone, sandy shale, and pure shale. These basal beds for 100 or 200 feet up are thoroughly impregnated with oil and have a dark-brown color due to staining, a strong odor, and a curious mode of fracturing characteristic of rock that is filled with bitumen. About 225 feet above the base is a hard zone ranging from 5 to 15 feet in thickness, made up of several calcareous sandstone layers and a rough mixture of ingredients of different kinds and textures. This zone of hard sandstone forms a prominent outcrop over the summit and down the sides of a hill just east of the road leading up Oil Canyon, appearing from a distance like a portion of the periphery of a huge wheel. Owing to the tendency of this bed to jut out over the surface of the hills, it was referred to as the "Reef beds" by F. M. Anderson,[a] and the name is here retained for convenience of reference.

Similar hard and soft sandstone beds continue to about 425 feet above the base of the formation, where a bed 10 to 20 feet thick of compact, white, diatomaceous and foraminiferal shale is sharply interbedded. This bed is prominent and so sharply marked off from the associated gray sand that it can be easily traced. It has been referred to throughout the field work as the "Indicator," and the name was found so convenient that it has been retained in

[a] A stratigraphic study in the Mount Diablo Range of California: Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, p. 175.

this report. The bed is continuous and in the same relative position everywhere, from Oil Canyon to the northern edge of the area shown on the map, beyond which no attempt was made to trace it. Southwest of Oil Canyon it is continuous for a mile or two at least. It preserves its strong individuality throughout in spite of the fact that it changes in character locally from a soft, compact, earthy deposit, both massively bedded and finely laminated (as on the eastern side of Oil Canyon in the south-central part of sec. 20) to a hard, thinly bedded, white, porcelaneous or flinty shale and yellowish calcareous shale (as south of the Laval grade on the hill (elevation 2,024 feet) 8½ miles north of Coalinga in the western half of sec. 21). This bed, where not greatly indurated, may be seen with a lens to be full of diatom remains—in fact, the rock seems to be chiefly composed of them. It is strikingly similar to the siliceous shale characteristic of the upper part of the Tejon (p. 23), and of the Santa Margarita formation of Reef Ridge (p. 37).

Above the "Indicator" bed soft gray and brown sandstones in thin layers make up a variable zone about 125 feet thick. This sandstone contains typical Vaqueros (lower Miocene) fossils, and is the uppermost horizon at which they are found. It grades above into soft, fine, grayish-white sand that looks bluish from a distance—the well-known "Big Blue." The latter zone being unfossiliferous, the line for the top of the Vaqueros formation is drawn at its base.

Southwest of Oil Canyon the Vaqueros beds become much thinner, and within about 2 miles they lose their prominence. In the hills for 2 miles north of the head of Pleasant Valley the beds are largely hidden by recent deposits of soil, alluvium, and gravel, but it is probable that a small thickness of beds, representing a part of the Vaqueros, is continuous. Their presence is doubtfully indicated by certain fossils that have been found.

Alcalde Hills.—In the hills west of Coalinga the Vaqueros is absent north of the San Joaquin coal mine, with the possible exception of a thin discontinuous zone locally exposed beneath the Santa Margarita and Jacalitos formations. South of the coal mine incoherent and extremely fossiliferous beds of the Vaqueros formation, largely of yellowish and gray sand, overlap upon the Tejon and Chico (Upper Cretaceous). Here, as in the Eastside field, they are about 500 feet thick. The sand is both coarse and fine, roughly bedded, and has partings and lenses of hard sandstone and gravel. Although it is fossiliferous, the fossils are poor and not certain as indicators. A section of the Vaqueros and overlying formations from Anticline Canyon to the Lucile oil well is given under the discussion of the developed territory (p. 101). Farther west a capping of low-dipping beds of this age extends over the ridges formed of steeply dipping beds of the Knoxville-Chico. This capping is, for the most part, only slightly indurated sand, clay, and gravel of many varieties of color and texture.

Jacalitos Hills.—Between Waltham Creek and the northern end of Reef Ridge the Vaqueros has not been recognized, but it may form a belt around the southeastern side of Curry Mountain, through the area tentatively mapped as covered by the Jacalitos formation, and thence continue southward, beyond the limits mapped, to join the belt on Reef Ridge.

Reef Ridge.—The Vaqueros overlies the shale of the Tejon on Reef Ridge and forms the steep face of the ridge. Southward from the region around Pleasant Valley the deposits thicken, and, owing to greater induration, form a more conspicuous part of the landscape than the contemporary beds farther north. Their relation to the underlying shale of the Tejon is probably unconformable, although no wide disparity in dip has been observed. There is even an apparent gradation from the shale below to the sandstone above in some places, making it difficult to determine the exact contact between the two formations. This difficulty is largely due to the lack of continuous exposures near the contact.

The Vaqueros is subject to considerable variation from place to place, as will be shown in the tabulated sections on page 35. It may in general be divided into three parts, one of comparatively soft beds of sandstone with shaly sandstone at the base, comprising about one-fourth of the total thickness; a second of hard, fossiliferous beds of sandstone with some conglomerate, making up about half of the formation and producing the prominent outcrops of Reef Ridge; and a third similar in thickness and character to the first and grading into soft, fine-grained beds that are poorly exposed and lead the observer to think there is a transition to the shale of the Santa Margarita formation above, although this is hardly supposable. The third part is much thicker on Canoas Creek than elsewhere, and there makes up half of the formation. The Vaqueros sandstone is thicker in the southeastern than in the northwestern half of Reef Ridge, the thickest section observed being 900 feet, on Canoas Creek. The middle part is marked by three principal horizons of hard fossiliferous sandstone and conglomerate beds, that stand out in strong relief. The lowest and middle beds are about 150 to 200 feet apart and the middle and uppermost beds 100 feet apart on the average. They vary in relative prominence from place to place and the exact horizon at which the induration is most pronounced is variable.

The following sections give an idea of the character of the Vaqueros as it occurs typically exposed along Reef Ridge:

Section of Vaqueros formation in Canoas Canyon.

	Feet.
Soft fine sandstone with large oil seepages; "Button beds" at base containing *Astrodapsis*, etc.; overlain by siliceous shales of the Santa Margarita formation	180
Hard and soft, gray and brown-stained sandstone, with large oil seepages in upper half	300
Massive sandstone beds with thick, very prominent hard beds at top and at base, the "Reef beds;" fossils at base	100
Sandstone with very prominent hard bed at base	200
Fairly hard, thin-bedded sandstone underlain by the Tejon formation	120
	900

Section of Vaqueros in Big Tar Canyon.

	Feet.
Soft sandstone and sandy shale, apparently a transition zone from Vaqueros to Santa Margarita	200
Two extremely hard fossiliferous sandstone and conglomerate beds, each about 10 feet thick ("Reef beds," with less prominent, softer sandstone between)	75
Coarse sandstone	150
Thin-bedded hard sandstone and shale, with reddish-brown shale at base	100
Massive, fairly soft grayish-brown sandstone	50
Soft sandstone with oil-stained streaks all through, overlying purple shale of Tejon; spring of tarry oil at base	200
	775

Importance with relation to petroleum.—The Vaqueros sandstone constitutes the principal reservoir for the petroleum in the Coalinga district. The oil enters the formation from the underlying Tejon and collects most abundantly in certain favorable zones within the formation, chiefly at its base, although permeating locally the whole formation in lesser amounts. The summit of the formation, as mapped, being overlain by the "Big Blue" north of Coalinga, it is coincident with the top of the productive zone in the Eastside field. Similarly it is believed that the productive zone in the Kreyenhagen field does not reach higher than the Vaqueros, the formation being there overlain by the impervious shales of the Santa Margarita. The relation of the formation to the occurrence of the petroleum is discussed more fully elsewhere. (See p. 69.)

SANTA MARGARITA FORMATION (UPPER MIDDLE MIOCENE).

General description.—A zone of beds full of very large fossil oysters and barnacles runs through the midst of the developed oil territory in the Eastside field and is well known to those familiar with the field. Its fossils show that it belongs in the same portion of the geologic column as the Santa Margarita formation[a] in San Luis Obispo

[a] Fairbanks, H. W., Geologic Atlas U. S., San Luis folio (No. 101), U. S. Geol. Survey, 1904.

County, farther toward the coast. This formation belongs in the upper part of the middle Miocene. No fossils have been found in the beds immediately below or above the *Tamiosoma* zone, as the fossil beds referred to may be termed, from the typical and restricted occurrence in them of the large barnacle of that genus, but the beds below and above, for a thickness of several hundred feet, are for the present mapped in the same formation with the fossil beds because they are closely associated with them and to all appearances form a part of the same succession. The Santa Margarita formation is traceable only as far south as the San Joaquin coal mine. Beyond that the beds are either lacking or are unfossiliferous, so that it can not positively be stated that they are the same. In a region such as this, where the beds are so variable from place to place and the different formations so similar, the fossils furnish the only evidence of contemporaneity that holds good. In the Kreyenhagen field, therefore, where the portion of the series between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene), corresponding to the portion occupied by the Santa Margarita farther north, is made up of unfossiliferous, hard, largely white, siliceous shales, it can not be stated definitely whether or not a continuation of the Santa Margarita occurs. The break in the geologic column between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene) is great, covering the whole of middle Miocene time, and is represented only in its later part by the *Tamiosoma* zone and associated beds. The Monterey formation (early middle Miocene) of the region nearer the coast is lacking. It is possible that the beds overlying the Vaqueros formation in the two parts of the Coalinga district represent different divisions of the later part of the middle Miocene period, that in the Kreyenhagen Hills being perhaps later. The rocks in the two fields are for the present mapped as one formation, the Santa Margarita.

Coalinga field.—The basal part of the formation mapped as the Santa Margarita is the "Big Blue." This consists usually of about 300 feet of light-gray fine sand and clay that appears to have a light-bluish tinge, especially when moistened; locally it includes other materials, causing it to be one of the most varied zones in the region. It is recognized in the oil wells as a sticky and frequently tough sand and clay immediately overlying the oil sands. Toward the northern edge of the area mapped it becomes coarser and is made up largely of fine-grained, coarse-grained, and bowlder beds composed of serpentine fragments, evidently derived from an area of serpentine to which the basin of deposition was in close proximity. Some of these serpentinous beds are extremely hard and form prominent buttes in which the decaying serpentine presents a variety of shades of light blue, green, brown, and dark red.

The "Big Blue" is overlain by the *Tamiosoma* zone which comprises a thickness of about 175 feet of fossiliferous, fine, medium-grained and locally gray sand and some sandy clay. This in turn is overlain by 400 to 500 feet of alternating beds of fine sand, sandy clay, coarser sand, and gravel up to the base of the prominent and thick gravel zone considered as marking the base of the Jacalitos.

Toward the southwest the Santa Margarita formation disappears east of Oil Canyon, being overlapped by the Jacalitos. It is not known just where the overlap occurs, because the beds are poorly exposed and cease to have distinguishing characters. On the western side of Pleasant Valley the *Tamiosoma* zone reappears and overlaps directly upon the Tejon (Eocene) at the San Joaquin coal mine. This is the southernmost point at which the fossils of this zone have been found within the district, and south of there the *Tamiosoma* zone is either absent or overlapped by the Jacalitos formation. There is present, however, beneath the fossiliferous Jacalitos beds, between the coal mine and Waltham Creek, a zone of bluish and grayish clay, about 250 feet thick, mapped with the Vaqueros of that area, that may possibly represent the same horizon as the "Big Blue" in the Eastside field. If this be true, it indicates a closer relationship of the "Big Blue" to the underlying Vaqueros than to the Santa Margarita, with which this zone has been described. This zone is described in the geologic section from Anticline Canyon to the Lucile oil well, page 101.

Kreyenhagen field.—The Vaqueros sandstone all along Reef Ridge is overlain by a formation of purplish, white, and brownish siliceous and argillaceous shale, having a thickness varying between 50 and 1,200 feet. The thin sharp beds of shale dip steeply away from Reef Ridge to the northeast, their upturned edges being exposed in a belt, usually only a few hundred feet wide, that follows the face of the ridge. This belt is likewise a topographic feature, owing to the resistance of the beds, which produce a line of shoulders or knobs on the small lateral ridges descending toward the foothills. Southeast of Little Tar Canyon the ridge of the Pyramid Hills, composed entirely of the shale, is a still more marked expression of this topographic influence, which is likewise characteristic of the formation elsewhere. The features described make this shale easily recognizable as a lithologic unit with strong individuality, and distinguish its main portion markedly from the Vaqueros sandstone (lower Miocene) below and the soft sandstone beds of the Jacalitos (upper Miocene) above. As before stated, this shale is only tentatively referred to the Santa Margarita and may or may not have originated at the same time as the coarser beds in the Coalinga field. Fossils found a few miles to the northwest, in Waltham Valley, indicate that the shale belongs to the

Santa Margarita. The shale may be a deep-water equivalent of the coarser sediments in the Coalinga field, which at the northern end of the field are of a strikingly littoral nature.

Near the southeastern end of Reef Ridge and along the ridge of the Pyramid Hills northeast of Dudley the shale has a thickness of from 1,050 to 1,200 feet. It is divided into two main portions, the lower of which consists of harder, more siliceous, and more thinly laminated purple and white shale, and the upper of softer, more argillaceous, brownish shale. The lower portion is the more conspicuous, constant, and typical; the upper is not so well exposed, is more variable in character, and is not definitely separable from the soft sandstone and shale of the formation overlying. The following section is typical of the formation along the face of Reef Ridge at its southeast end, the different zones noted not being sharply separated from one another.

Section of Santa Margarita formation 3½ miles southeast of Big Tar Canyon.

	Feet.
Soft, brownish, clay shale poorly exposed, grading above into the fine sandy shale at the base of the Jacalitos formation and below into bluish-purple siliceous shale with occasional hard, more siliceous layers	400
Hard, siliceous, porcelaneous, thinly bedded shale, lavender colored, but weathering white, with prominent iron stain throughout along joints; breaking with angular and conchoidal fracture into elongated, sharp-edged pieces; interbedded with occasional soft laminæ	250
Fairly hard, purplish, siliceous and argillaceous shale, finely fractured into needle-like fragments with yellow calcareous concretionary lenses and interbedded porcelaneous layers; overlies the Vaqueros	400
	1,050

The two lower of these three zones differ largely in the proportion of hard beds that they contain, and, as this proportion is variable from place to place they do not form continuous belts distinct from each other. Together they make up the lower portion of the formation according to the division given above. The siliceous shale of the lower portion varies in amount of induration, ranging from a dull, opaque rock that may be scratched with the finger nail to a subvitreous flinty variety that can not be scratched by a knife. It resembles very strongly the altered varieties of shale of the Monterey formation (middle Miocene) that occurs nearer the Pacific coast, and the shale of the Tejon and the "Indicator" bed of the Vaqueros of this district. Like these, its less-altered varieties show traces of thickly embedded round dots and flakes that are almost certainly the remains of diatoms, and the shale has the characteristic flaky texture of diatomaceous material. The more siliceous shale seems to be made up almost entirely of the crushed diatom tests. It contains also fish scales and other particles of organic origin, but almost no molluscan remains. The shale laminæ are locally yellowish and calcareous and similar to the foraminiferal shale of the Tejon. Southeast of Little Tar Canyon the formation increases in thickness to about 1,200 feet, the increase being mostly in the brownish shale of the upper portion. The base of the formation is approximately at the axis of the anticline of the Pyramid Hills. The shale appears on both sides of McLure Valley with a general steep dip toward the valley and with little change in lithologic character or thickness.

The northernmost point at which the siliceous shale doubtfully ascribed to the Santa Margarita formation has been recognized in this district is at the northwest end of Reef Ridge, where the white shale forms a thin zone between the underlying and overlying sandstone formations. It has a thickness of only about 50 feet. On the west side of Jasper Canyon, the Vaqueros is overlain by hard, brittle, yellowish-brown and black clay shale that may be a continuation of the Santa Margarita, but its relations have not been studied. A zone composed in large part of shale continues in the same position in the series at least as far as the main valley of Jacalitos Creek, to the northwest. This zone is highly tilted and much broken up.

Southeastward along Reef Ridge the shale thickens gradually and continuously. Southwest of the head of Zapato Creek there is about 200 feet of shale that is divided into two zones of about equal thickness. The lower one is of siliceous shale weathering purplish, brownish, and white, similar to that forming the prominent outcrops of this formation elsewhere. The upper is of purplish and brownish largely clay shale. This grades at the top into alternating beds of brown sandstone and dark clay shale, which make up a thickness of several hundred feet and which may or may not be a part of the same formation. It is possible that this sandstone and shale correspond to part of the thickness of shale found farther southeast, but, fossil evidence being lacking, the formation is restricted for the present to the beds that are purely shale. The most rapid thickening of the formation takes place between Zapato Canyon and Canoas Canyon. At the latter it is about 650 feet thick and comprises three almost equal zones—the lowest of fine-grained purplish shale of medium hardness, fractured into fine, needle-like, angular fragments; the middle of hard, siliceous white shale; and the upper of soft brownish shale.

The same siliceous shale is found south of the Coalinga district, extending along the border of the San Joaquin Valley. It thickens from the northwest end of Reef Ridge toward the south until at the Temblor ranch, in western Kern County, it attains the remarkable thickness of 5,400 feet. It is probable that a part of the formation here stands for a period of time not represented by deposits in the region of Reef Ridge and may coincide with a part or all of the Monterey formation (middle Miocene). The thickening of the shale southward may take place at its base, the beds in the Coalinga district representing an unconformable overlapping of the upper portion upon the Vaqueros.

Importance with relation to petroleum.—In the Coalinga field the Santa Margarita formation has an important relation in different ways to the occurrence of the petroleum. In the Eastside field its base is taken as extending down through the "Big Blue." This zone caps the Vaqueros sandstone, or productive zone; and although small amounts of oil and tar are found above its base, there is none in commercial qualities. The Santa Margarita is of chief importance here as forming an impervious capping which has held the oil in. In the Westside field the formations are thinner, and sand beds of the Santa Margarita become part of the productive zone. In the Kreyenhagen field the shale of the Santa Margarita acts, as the "Big Blue" does, as an impervious capping that keeps the oil confined within the Vaqueros beds.

JACALITOS FORMATION (EARLY UPPER MIOCENE).

Definition and general description.—The formation overlying the Santa Margarita in the Kreyenhagen Hills consists of about 3,600 feet of sand, gravel, clay, and sandstone, in places very fossiliferous, and was formed in the earlier upper Miocene time. It is here named the Jacalitos formation owing to its characteristic exposures both north and south of the creek of that name. Abundant and well-preserved fossils, by means of which its age is determined, occur in the type locality. It is probably the equivalent of parts of one or more of the upper Miocene formations known in other parts of the State, but its definite relations to these have not yet been worked out. It is in part represented in the northern portion of the district by similar beds aggregating a much smaller thickness.

In the fields this formation does not stand out prominently as a lithologic or stratigraphic unit and is not readily distinguishable by itself. On the contrary, it forms merely a portion of the great thickness of apparently conformable Tertiary beds that are exposed in the great monocline, dipping at medium and high angles toward the valley. The formation may be roughly distinguished as that portion of the series between the shale of the Santa Margarita below and the major beds of blue sand that are characteristic of the lower part of the formation above it (the Etchegoin) throughout the district. The Jacalitos, however, includes a great thickness of blue-sand beds at its summit in the southeastern part of the Kreyenhagen Hills. A feature of this formation is the occurrence at intervals in it of hard zones that project like saw teeth and by their resistance protect the beds immediately above and below them, thus forming long parallel ridges. The same feature is in a greater measure characteristic of the Vaqueros sandstone and Santa Margarita formation below and less so of the Etchegoin (uppermost Miocene) formation above. Another feature of the Jacalitos is the great number of sand and pebble beds, full of sea urchins, that are found in all parts of the formation. This feature is likewise one belonging to the formation above. The most important features, however, and the only ones that can be relied upon to separate the Jacalitos from the other sandy formations, are the position that it occupies in the series and the various fossils that it contains.

The Jacalitos in the Kreyenhagen Hills is probably unconformable with the Santa Margarita below, although the two formations appear conformable at the contact, the line between them being arbitrarily drawn where the beds that are predominantly shale (Santa Margarita) give place to sandy beds (Jacalitos). In the northern part of the district the relation of these two formations appears also to be one of conformity, although the overlap of the Jacalitos on the Santa Margarita near Oil Canyon proves clearly that it is the opposite. The line there also is drawn arbitrarily at the base of the prominent pebble zone full of fossil wood. The Jacalitos is likewise conformable to all appearances with the later Miocene (Etchegoin) beds which rest above it and are largely similar in composition, the line between these two formations being likewise drawn somewhat arbitrarily, chiefly on the basis of the fossil contents. There is a possibility that an unconformity between these two formations exists in the hills surrounding Pleasant Valley. (See p. 49.)

From its locality of typical occurrence in the Kreyenhagen and Jacalitos hills the Jacalitos formation extends southwestward into McLure Valley, where it occupies a similar position between the underlying Santa Margarita and the overlying Pliocene sands. Toward the northwest it reaches into the interior of the Diablo Range through the depression formed by the Waltham syncline and toward the north extends across Alcalde Canyon into the region around Pleasant Valley. North of Jacalitos Creek it no longer rests upon the shale of the Santa Margarita, that formation being lacking, and the Jacalitos ceases to be completely represented. The question of the relations of the beds of this age in the northern and southern portions of the district is complex and can be decided only on the basis of detailed paleontologic evidence. The formation will be considered separately for the areas lying to the south and to the north of Waltham Creek.

South of Waltham Creek.—From Jacalitos Creek southward the Jacalitos formation affords more complete exposures than elsewhere. The type locality for its fossils is along that creek, near which representative faunas have been collected at several different points from different horizons, but the undisturbed monocline in the range of the Kreyenhagen Hills furnishes somewhat better sections of the formation as a whole, since it has suffered considerable disturbance along Jacalitos Creek and in the hills north of it. Moreover, in the latter region the base of the formation does not appear within the area shown on the map and has not been definitely traced. As before stated, the alternating beds of brown sandstone and dark shale that overlie the siliceous shale of the Santa Margarita about the head of Zapato Creek and thence westward are mapped with the Jacalitos, although it is uncertain to which formation they properly belong.

The following tabulated sections will give the best description of the lithologic character of the Jacalitos formation and its zones. It must be borne in mind, however, that the formation is variable from place to place; that any single description applies merely to a single locality; that the different zones noted are not sharply separable, but grade into one another, all containing elements in minor quantity common to the others, and that a great variety of sedimentary beds occur that would necessitate almost endless discussion to describe in detail. Although the formation is thus variable, part of the variation noticeable in the sections may be due to the fact that exposures are not complete and that beds and fossils apparent in one place are frequently hidden in others. It is especially difficult to determine the relative quantitative importance of clay or somewhat compacted shale, for the reason that the firmer sand beds are better exposed and therefore appear to dominate, and because it can not always be determined whether the softer unexposed beds are fine sand or clay.

The following is a section of the Jacalitos along Jacalitos Creek, from the summit of the formation, at a point on the south side of the creek and at the north base of the 1,220-foot hill in the eastern part of sec. 31, T. 21 S., R. 15 E., to its contact with the prominent Vaqueros sandstone at a point not shown on the map, about 1½ miles west-northwest of the end of Reef Ridge, in the middle of sec. 11, T. 22 S., R. 14 E.

Section of Jacalitos formation on Jacalitos Creek.

	Feet.
Bluish to brownish-gray clay and clayey sand, alternating with light-gray and olive-gray pebbly sand, with occasional hard fossil layers and with *Pecten estrellanus* bed at base; overlain by blue sand at the base of the Etchegoin	750
Massive beds of buff and olive-gray sandstone and sandy clay interbedded with thin and thick beds of olive-gray pebbly sandstone and gravel, and occasional sandstone layers. Sand dollars (*Echinarachnius*) numerous throughout, usually in the pebbly layers. Bed of dark-brown sandstone at base (at forks of Jacalitos and Jasper creeks), containing a rich fauna, including *Chione, Macoma, Panopea, Echinarachnius*, etc	1,300
Alternating heavy beds of coarse gray and brown sandstone and thin beds of fine sandstone and sand of the same colors, with some beds of gritty olive-gray sandstone and hard fossil layers. Bed with large *Astrodapsis* 200 feet above base. Probably the zone of *Trophon* found farther southeast	500
Alternating beds of grayish and brownish sand and sandstone, with some sandy clay and fossil layers in the sandstone	750
Alternating beds of soft gray and brown shale and sandstone, much tilted and fractured, and in part overturned	500+
	3,800+

The basal portion of this section rests upon the continuation of the steeply tilted Vaqueros sandstone that is so prominent on the face of Reef Ridge. Shale similar to the typical shale, mapped as Santa Margarita, is entirely lacking; but it is possible that the much disturbed basal zone of this section is the equivalent of that shale. It may be the continuation of the similar thickness of alternating beds of brown sandstone and dark shale overlying the typical shale of the Santa Margarita along Zapato Creek, which has been mentioned (p. 42) as doubtfully referred to the Jacalitos instead of to the Santa Margarita formation. There is a possibility that this zone of alternating beds, which is for the present considered as the basal portion of the Jacalitos, may be unconformable with the main body of that formation, but further work will be required in order to determine this.

The middle portion of the Jacalitos formation, in this locality especially, contains large unconsolidated accumulations of fine pebbles, some in thick beds by themselves and some interbedded in thin layers in the sand beds or scattered throughout the sand. These coarse beds are frequently fossiliferous, and sand dollars are especially abundant in them.

The uppermost beds of the above section underlie the lowest of a number of prominent blue-sand beds that are characteristic of the landscape in this district along the belt of Etchegoin (Pliocene) formation. The line of contact between the Jacalitos and Etchegoin formations is drawn somewhat arbitrarily on the basis of this lithologic break and of the characteristic *Mytiloconcha* and *Glycymeris* fauna that occurs in a bed just above. The beds above and below this line of contact dip with perfect conformity at an angle of about 25°.

The following is a section along Canoas Creek from the top of the Jacalitos, immediately south of the house of Hugo Kreyenhagen, to its contact with the Santa Margarita:

Section of Jacalitos formation along Canoas Creek.

	Feet.
Chiefly grayish sand and soft sandstone, with thick pebbly zone containing *Pecten estrellanus* at base; fossil bed with *Cardium, Solen, Echinarachnius, Macoma, Nassa, Olivella*, etc., at top	650
Chiefly massive gray and buff-colored coarse-grained sand; a prominent bed of friable dark sandstone with *Panopea*, etc., at base	1,000
Similar sand, with prominent ridge-forming bed at base	350
Similar sand, with prominent bed, the zone of *Trophon*, etc., at base	400
Similar sand, with occasional sandstone layers and with prominent sandstone bed at base, forming first hill northeast of Reef Ridge	500
Similar sand, grading below into sandy shale, overlying the Santa Margarita	600
	3,500

Southeast of Canoas Creek the Jacalitos formation preserves a character and thickness very similar to that given in the above sections.

The fossiliferous sandstone beds become more indurated, so that they stand out like sawteeth on the summits of longitudinal ridges most of the way to Big Tar Canyon and form very pronounced features of the landscape. As this canyon is approached the beds assume steeper and steeper attitudes until they dip uniformly at angles varying between 50° and 60°. The chief new feature assumed by the formation in this region is that some of the sand and pebble beds in its higher portion have the blue color characteristic of the basal beds of the Etchegoin. Confusion is thus introduced into the separation of the two formations, but the same paleontologic criteria used in distinguishing them elsewhere still hold good here. In the neighborhood of Garza and Big Tar creeks the zone of blue sands extends down over 800 feet into the Jacalitos, whereas farther southeast, as shown in the next section, it extends to a still lower horizon, the lowest at which it has been found anywhere. The exact similarity of the beds above and below the contact of this formation with the overlying Etchegoin, together with their perfect angular conformity, is almost conclusive evidence of their actual conformity and continuity.

Southeast of Big Tar Creek the beds begin to lose prominence and to form nearly uniform rolling hills of soft sand, with few large exposures. The dip in this region becomes uniformly about 60°. The following section shows the character of the formation at about the farthest point southeast in the Kreyenhagen Hills at which a section of satisfactory completeness can be obtained from the surface exposures:

Section of Jacalitos formation on north side of Reef Ridge 3½ miles southeast of Big Tar Canyon.

	Feet.
Dark-gray sand with about 20 feet of light-blue sand at base	120
Olive-gray sand with light-blue sand at base; the basal portion is probably the main *Pecten estrellanus* zone found 1 mile northeast	350
Fine shaly yellowish-gray sand, with whitish-gray and dark-gray layers interbedded and some bluish pebbly sand; the lowest blue sand is at base	720
Compact, medium-grained to coarse gray sand, like beach sand	275
Olive-gray speckled sand and soft sandstone with appearance of a pepper-and-salt mixture	275
Interbedded fine and medium grained grayish, whitish, and yellowish sand and speckled sand like the last, with some clay layers	600
Fine and medium grained reddish, yellowish, and grayish sand and soft sandstone with white sandy clay at top and coarse pebbly sand 300 feet below top; grading at base into soft whitish-gray sandy shale	1, 200
	3, 540

The Jacalitos is worn off over the summit of the Pyramid Hills anticline but reappears on its southwestern flank on the north side of McLure Valley, dipping under the alluvium of the valley floor. The descriptions of the formation already given apply to it as it appears in this region. The exposures are in general poor.

The succession of beds exposed on the western flank of the high hill 1 mile southeast of Alcalde, east of the road leading southward from Alcalde toward Jacalitos Creek, comprises about 1,600 feet of sand, clay, gravel, and fossiliferous sandstone up to the base of the blue beds that mark the Etchegoin formation. Locally, on the flank of this hill the beds have a slight stain resembling that due to the presence of oil. West of this road above mentioned the Jacalitos beds are chiefly sand, with some clay and gravel and with fossils. They overlap upon the steeply tilted Cretaceous strata and are warped into a number of low plunging folds. Still farther west the Jacalitos overlaps a wide extent of country in the Waltham syncline, along which it has been traced 6 miles west of the area shown on the map along Jacalitos Creek as far as the road to Stone Canyon.

Alcalde Hills.—North of Waltham Creek the Jacalitos formation loses the great thickness that characterizes it throughout its occurrence to the south, retaining a thickness of only about 800 feet. This thinning takes place very rapidly in the immediate vicinity of Waltham Creek, as it does in the case of the Etchegoin formation as well, indicating that the lower portion of Alcalde Canyon follows a line that has been an extremely important locus of orogenic movements. The areas to the north and south thus separated have had in large measure a different geologic history. The exact nature of the thinning that takes place in the Jacalitos has not been determined; whether it is a constant thinning affecting all of the beds of the formation or whether it is due to the absence of some large parts of the formation, owing either to their having never been deposited north of Waltham Creek or to their having been worn away, is not known at present. It is believed that the area north of Waltham Creek was land during the earlier part of Jacalitos time and that the lower portion of the formation was never deposited there.

The formation over the area of the Alcalde Hills retains the general character of the beds to the south. It is a variable formation of incoherent yellow, brown, and gray sand, sandstone, clay, and gravel, locally containing fossils such as *Pecten estrellanus*, *Pecten oweni*, a large species of *Metis*, and a large sand dollar of the genus *Echinarachnius*. The typical fauna of the lower part of the formation in the type locality along Jacalitos Creek is not present. The beds are evidently of near-shore origin, being in many places roughly bedded, cross-bedded, and variable. They are full of gypsum. The base of the formation as mapped is a fossiliferous bed, containing *Pecten estrellanus*, and other fossils, that is traceable southward from the San Joaquin coal mine to Waltham Creek. It is underlain, conformably so far as known, by a zone of clay and fine sand about 300 feet thick, which has been mentioned before (p. 37) as possibly belonging to the Santa Margarita but which is mapped with the Vaqueros. The summit of the Jacalitos formation is mapped at the base of the *Glycymeris* zone, which is the equivalent of the basal Etchegoin as found elsewhere. The relation of the beds along this contact is also conformable so far as observed. A section of this and the associated formations will be found on page 101.

North of Pleasant Valley.—The beds correlated with the Jacalitos in the northern part of the district form that part of the series on Joaquin Ridge which lies between a prominent zone of gravel at the base that outcrops typically on the hill (where the tanks are situated above the Standard Oil Company's wells, on the west side of the NE. ¼ sec. 28, T. 19 S., R. 15 E.) and the base of a zone of gray sand with abundant fossils outcropping typically on the hill where one tank stands, in the NE. ¼ SW. ¼ sec. 34, T. 19 S., R. 15 E. This portion of the series consists of about 1,600 feet of alternating fine gray sand and clay, pebbly and medium-grained sand and sandstone, and gravel. The basal pebbly zone has a thickness of about 150 feet, of which the lower half is a solid layer of pebbly gravel, locally hardened to conglomerate, and the upper half thin-bedded, brown, gray, and in some places pinkish, sandstone and sand intermingled with pebbles and with occasional shaly layers. This zone contains a great abundance of petrified wood in large fragments, and at one place a tooth of an extinct species of horse was found in it. The rest of the formation is mostly soft, fine sand, with which hard sandstone layers, pebbly sand, and sandy clay beds are frequently interbedded. Several pebbly zones have considerable thickness, but no part of the upper portion has distinct individuality or prominence, and very few fossils have been found in it.

Importance with relation to petroleum.—The Jacalitos formation is not petroliferous in the Eastside field in the northern part of the district, but is very productive in the Westside field owing to the thinning out of the formations between it and the Tejon. In the Kreyenhagen field it is not known to be productive at any point, no oil having escaped from the Tejon and Vaqueros through the shales of the Santa Margarita. The thickness and character of the Jacalitos throughout the district have an important bearing on the question of the accessibility of the oil, owing to the fact that most of the wells have to penetrate it in order to reach the oil sands at depths at which they will be productive. A knowledge of its thickness has been especially useful in making calculations as to the depth at which the oil sands may be found in the Kreyenhagen and Kettleman hills.

ETCHEGOIN FORMATION (UPPERMOST MIOCENE).

Definition and general description.—The name Etchegoin was applied by F. M. Anderson[a] to a great thickness of beds of unconsoli-

[a] Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: Proc. California Acad. Sci., 3d ser., vol. 2, No. 1, 1905.

dated sand, gravel, and clay, characteristically blue at the base, occurring typically in the vicinity of the Etchegoin ranch, 20 miles north of Coalinga, and extending continuously from there both northwest and southeast along the border of the Diablo Range. In accordance with Mr. Anderson's statements and on the basis of the reasons stated below the Etchegoin formation is mapped and described in the present paper as the succession of slightly consolidated beds of sand, gravel, and clay occurring on the summit and flanks of Anticline Ridge and on the southeast end of Joaquin Ridge north of Coalinga, above the base of the hill-forming sandstone beds (referred to for convenience as the *Glycymeris* zone), and below the beds described as the Paso Robles formation. Strata in other portions of the Coalinga district are referred to the Etchegoin formation on the basis of paleontologic correlation with the beds on Anticline Ridge.

The *Glycymeris* zone is an extremely fossiliferous bed of somewhat indurated sand that forms the summit of the hill at the northwest end of Anticline Ridge (in the NW. ¼ SW. ¼ sec. 34, T. 19 S., R. 15 E.) and extends continuously from that point along the line mapped as the base of the Etchegoin formation. It is underlain at the locality referred to by clay that is classed in the Jacalitos formation and is overlain by a thick succession of bluish-gray sand beds interbedded with dark-gray sand. The zone affords almost perfect specimens of many species of fossils that make up a distinctive fauna. It is called the *Glycymeris* zone for ease of reference, because it is an important datum line that may be recognized by the association of fossils contained in it.

There are various reasons for assuming this zone to be the base of the formation. First, an unconformity is known to occur below it in the synclinal basin north of White Creek, for there a zone containing the same fauna rests directly upon Cretaceous (Chico) sandstone, and somewhere between Oil Canyon and the Cretaceous area an unconformable overlap of the *Glycymeris* zone upon the underlying Tertiary beds must exist. It is therefore appropriate to consider the beds above the base of the *Glycymeris* zone as a distinct formation, although on Anticline Ridge and in the greater portion of their extent in the region north of Coalinga, as well as to the south as far as they have been studied, they appear to rest conformably upon the beds below. A further reason for assuming this zone as the base is that it is at the bottom of a succession of bluish sand beds on Anticline Ridge and at some other places in the Coalinga district, thus marking a sharp and easily recognizable variation in lithology between the beds below and above it. At other places, however, especially in the southern portion of the Kreyenhagen Hills, the blue sands occur also far below the *Glycymeris* zone, so that the lithologic feature can not be relied upon everywhere as a basis of separation.

In the description of the Jacalitos (early upper Miocene) frequent reference has been made to the overlying Etchegoin (late upper Miocene). In fact, these formations are so closely related and so similar that the one can not well be described without reference to the other. In places they seem to have originated as a chronologically continuous succession of marine deposits and are only arbitrarily separable, whereas in other places an overlap of the latter upon the former has taken place. Many of the features of structure, influence on topography, and lithologic variability mentioned in connection with the former exist also in the latter.

The Etchegoin formation consists of slightly consolidated sand, clay, and gravel, interbedded with occasional indurated beds, and is characterized by an abundance of invertebrate fossils, among which a few forms like sand dollars (*Echinarachnius*), barnacles (*Balanus*), *Mulinia*, *Arca*, *Mya*, small oysters, *Neverita*, etc., are particularly prevalent. It reaches a thickness of over 3,500 feet in the southern portion of the district, but in the northern portion it is at most only half as thick. It may be most easily recognized by the dominant grayish-blue color of the massive sand beds that comprise a thickness of several hundred feet at its base, but an examination of its characteristic fossils is the only means of distinguishing it accurately from the associated formations.

One of the most important of its broad features in the Coalinga district is the usual predominance of coarse material, such as sand and pebbly deposits, in its lower portion, and of finer material, such as extremely fine sand and clay, in its upper portion; but this feature is characteristic in various degrees according to the locality, and in some places is hardly noticeable.

Coalinga field.—In the oil field north of Coalinga the Etchegoin has a thickness of about 1,700 feet. The basal *Glycymeris* zone has already been described. Several other fossiliferous beds occur within several hundred feet above this, and contain abundant sand dollars (*Echinarachnius*), barnacles (*Balanus*), cardiums, turritellas, etc. The lower portion of the formation is composed largely of beds of compact coarse and fine blue sand alternating with zones of pebbly sand, fine gray sand, and some clay, with occasional more hardened beds. The clay increases toward the upper part of the formation, being interbedded with unconsolidated light-gray sand that spreads over the surface and obscures the structure. The formation occurs in the low hills bordering the valley and passes beneath the alluvium of the floor.

The Etchegoin forms a belt along the edge of the Alcalde Hills west of Coalinga and is overlapped by the recent valley deposits. A good section of it is obtainable 2 miles southwest of Coalinga, where the fossiliferous beds of the *Glycymeris* zone at its base outcrop on the west side of the summit of a prominent hill on which a tank is situated, in the SE. ¼ sec. 1, T. 21 S., R. 14 E. These beds are of yellowish gypsiferous sand and sandstone of fine to medium grain, with a thickness of about 200 feet. They are overlain on the top of the hill by 200 feet of both loose and indurated coarse gravel, pebbly sand, and interbedded fine sand containing sand dollars. Above these beds comes a thickness of 250 feet of whitish-gray sand of the texture of granulated sugar, grading at the base into coarser even-grained sand. This zone is followed above by about 20 feet of coarse sand, sandstone, and pebble conglomerate containing many fossils, including *Pecten wattsi*, *Arca*, *Ostrea* (small), sand dollars, sea urchins (*Astrodapsis*), etc. This is the zone of *Pecten coalingaensis* that occurs in the Kettleman and Kreyenhagen hills. (See p. 50.) The highest beds exposed are of fine yellowish and whitish-gray sand comprising a thickness of about 50 feet, these being overlain by the surface deposits at the base of the hills. The thickness of the formation in this section is about 700 feet, but as the uppermost beds that belong above the *Pecten coalingaensis* zone are hidden, the whole formation probably has a thickness of about 900 or 1,000 feet.

White Creek basin.—A detached area of Etchegoin beds is preserved in the syncline near the head of White Creek, northwest of Coalinga, where the formation rests upon the beds of the Cretaceous (Chico). At one time these beds were doubtless continuous with those of the same formation around Pleasant Valley, and their presence in this interior basin proves that an extended overlap of the Etchegoin over the older Tertiary formations and onto the Cretaceous took place.

The basal beds appearing above the Cretaceous in this syncline are very fossiliferous and contain a finely preserved fauna exactly similar to that of the *Glycymeris* zone on Anticline Ridge. They may be regarded as representing the same horizon. The lowest 100 feet of beds immediately overlying the Cretaceous are composed of coarse and pebbly, compact but soft, yellowish-gray sandstone hardly distinguishable from the underlying Cretaceous sandstone. These beds are not very fossiliferous, but grade upward into beds largely composed of fossils, with a matrix of yellowish-gray sand. *Arca* is the most abundant genus, but *Glycymeris*, sand dollars (*Echinarachnius*), and locally many other forms are also very abundant. The bulk of the formation in its middle portion consists of similar sand and sandstone resembling the massive upper Cretaceous sandstone and containing occasional fossil beds. Numerous layers of very hard sandstone and some concretions are present. The beds for a few hundred feet below the top of the formation are more variable, a thick zone of coarse pebbles being followed above by alternating beds of sandy shale, calcareous shale, and coarse and fine sand

and sandstone, and, near the top, a hard and prominent thin bed of dark-brownish sandstone full of small white fossils. The total thickness of the formation is about 1,100 feet, which corresponds fairly well with the thickness that it is supposed to possess in the hills west of Pleasant Valley.

Kreyenhagen Hills.—The best and most complete sections of the Etchegoin may be found in the Kreyenhagen Hills, where the upturned northeastward-dipping beds of this formation are exposed as a belt in the foothill area between the Jacalitos and the Paso Robles. It is not easily separable from these two formations, the line at the base being especially arbitrary. The contact at the base of the Etchegoin is drawn below a fairly constant fossiliferous zone, supposed to be the equivalent of the *Glycymeris* zone north of Coalinga. The contact at the top of the formation is marked by the usual occurrence above it of the gravelly beds of the Paso Robles, by the presence at the top of a zone containing *Mya*, *Ostrea*, etc., which may be called the upper *Mya* zone, and by other more local criteria.

The zone of blue-sand beds at the base of the formation is constant throughout the Kreyenhagen Hills. Its thickness is variable from place to place and is of little value except for broad correlations. The lower part of the formation is composed chiefly of sandy beds of all degrees of coarseness up to pebble beds, and of many varieties of blue, gray, and drab color, with minor amounts of clay. The upper part of the formation is composed of alternating thick zones of sand and clay, the amount of clay being somewhat greater than in the lower portion.

There are four main fossil zones in the Etchegoin of the Kreyenhagen Hills, corresponding to similar ones found in other parts of the district. The lower zone is the *Glycymeris* zone already mentioned. About 800 feet above the base of the formation, roughly speaking, comes a zone characterized by an abundance of *Mulinia* (large), *Arca*, sand dollars (*Echinarachnius*), etc., which may be referred to here and in the Kettleman Hills as the upper *Mulinia* zone, as it is the uppermost bed in which large specimens of this genus are found. This zone is usually coincident with the upper portion of the blue-sand zone. The third main zone may be called the *Pecten coalingaensis* zone, owing to the nonoccurrence of this species at other horizons. It is within 300 to 400 feet below the top of the formation and contains a well-preserved and extremely varied fauna, including *Pecten coalingaensis* and *Pecten wattsi* as about the most typical forms, together with many sand dollars, sea urchins, brachiopods, etc. The fourth zone includes the summit beds of the formation, which contain *Mya*, *Ostrea*, etc., and which are called the upper *Mya* zone. These four zones do not include all the important fossil beds in the formation, but are those that have been found most persistent and easily recognizable and therefore most valuable as datum lines.

The following columnar sections of the formation in different parts of the Kreyenhagen Hills give a tabulated description of the formation as it occurs typically and convey an idea of the variability of the beds:

Section of Etchegoin formation on Zapato Creek.

	Feet.
Light-gray and olive-gray sandy clay and sand, with sandstone layers at top containing *Mya*, *Ostrea*, *Arca*, *Neverita*, etc.; the upper *Mya* zone; overlain by gravel of Paso Robles formation	300
Olive-gray fine sand and pebbly sand, with thin sandstone layers. Rich fossil zone at top containing *Pecten wattsi*, *P. coalingaensis*, brachiopods, sea urchins, etc.; the *Pecten coalingaensis* zone	400
Bed of light-blue sand, the highest of the blue-sand zone	10
Massive beds of gray sand and sandy clay with occasional thick beds of blue sand; a bed containing *Arca* in quantities at the base	290
Similar gray and blue beds with a 20-foot zone at base composed of massive, olive-gray, compact sand containing many inconstant laminæ of hard brownish-gray sandstone	850
Gray sand	350
Prominent bed of cavernous-weathering blue sand	50
Alternating thick beds of gray sands and bluish clay, with thin layers of sandy clay, and with three prominent beds of blue sand in the lower 100 feet. This basal portion is probably the upper *Mulinia* zone	250
Olive and light-gray sand and sandy clay	500
Prominent beds of blue sand at top and base, with prominent massive beds of olive-gray medium-grained and pebbly sand and minor beds of clay and blue sand between; this is the base of the blue-sand zone and approximately that of the Etchegoin	475
	3,475

Section of Etchegoin formation on Canoas Creek.

Fine gray sand and clay with occasional hard layers; zone of *Mya*, etc.; overlain by gravel of Paso Robles formation	450
Gray sand and clay in alternating beds of variable thickness	1,700
Top of blue-sand zone; massive gray sand both coarse and fine, interbedded with clay in lesser amounts and occasional heavy beds of blue sand; contains numerous sand dollars and a zone at the base with *Mulinia*, *Cardium*, *Glycymeris*, *Mytiloconcha*, etc.; the upper *Mulinia* zone	550
Similar beds to the base of the zone of blue sand. Beds at base containing sand dollars (*Echinarachnius*) *Solen*, *Cardium*, *Nassa*, etc	900
	3,600

Section of Etchegoin formation 3½ miles southeast of Big Tar Canyon.

Thinly bedded hard white porcelaneous shale, with whitish-gray fine sand, pebbly sand, and sandy clay, containing lenticular layers and nodules of porcelaneous shale and many bone fragments	250
Alternating thick zones of whitish-gray sand and clay	1,080
Solid zone of thin-bedded pebbly sandstone	45
Whitish-gray sand and clay with a 15-foot bed of coarse pebbly sand in middle	660

	Feet.
Prominent beds of compact gray sand with softer sand and sandy clay between; whitish gray sand with black pebbles at base	210
Compact fine gray sand streaked with layers of fine whitish sand and sandy clay.	420
Compact, slightly gritty white shale somewhat similar to the Santa Margarita...	10
Solid zone of gray sandstone, coarse pebbly sandstone, and hard calcareous shale	40
Fine gray sand	50
Highest bed of blue sand, with a 10-foot layer of pebbles at base and a 3-foot layer full of sand dollars, barnacles, arcas, etc., 20 feet above base; probably upper *Mulinia* zone	80
Interbedded blue sand and sandy clay with a prominent 20-foot bed of blue sand at base; probably the zone of *Crepidula*, *Solen*, etc., found 1 mile to the northwest	120
Minor beds of blue sand, with a thick zone of hard calcareous shale in middle..	90
Prominent blue-sand bed, pebbly toward the base and containing many sand dollars	90
Soft gray sand	70
Very prominent blue sand	40
A prominent 30-foot bed of blue sand at base overlain by bluish and gray sand and three less prominent beds of blue sand	250
	3,500

McLure Valley.—The Etchegoin probably outcrops over a small area in the Avenal syncline in McLure Valley above the Jacalitos formation, and is characterized at its base by blue sands, but it can not be definitely recognized. The thickness of beds above the Santa Margarita in this region is so great that some Etchegoin must be present in addition to the Jacalitos. No fossils have been found, and there is no direct evidence on which to base a separation between the two formations, so that the line of contact mapped is arbitrary. The highest beds appearing in the syncline, which are taken to be the basal beds of the Etchegoin, consist of blue sands. Above these everything is covered by the recent alluvial deposits of the valley.

Kettleman Hills.—The Etchegoin is excellently exposed in the Kettleman Hills, where it is a thick formation similar in character to the same terrane in other parts of the district. Its lower portion appears along the axis of the Coalinga anticline, but although the lowest beds that the plunging anticline brings to the surface are very nearly the basal beds of the formation no underlying formation is known to be exposed. The uppermost beds appear all around the Kettleman Hills and are everywhere overlain, with apparent conformity, by the fresh-water beds at the base of the Paso Robles. The greatest thickness that has been found exposed is in the south-central part of the hills, on the southwestern flank of the anticline, where the beds below the fresh-water horizon measure over 3,000 feet.

Different horizons in the Etchegoin of the Kettleman Hills afford good datum lines that may be recognized by means of the characteristic faunas and the constancy of the beds containing them, and it is convenient to designate these briefly, beginning with the summit of the formation as a constant datum line and going down. The summit of the formation is marked, as it is in portions of the Kreyenhagen Hills, by a constant fossiliferous zone of sand and sandstone interbedded with dark clay, which here, as in the Kreyenhagen Hills, may be called the upper *Mya* zone, because of the great abundance of fossils of the genus *Mya.* It is also full of other fossils, small yellow *Littorina* and small oysters being especially common. This zone has a thickness varying between 200 and 300 feet, and is prominent in the topography because it usually forms a line of hills. In the southern part of Kettleman Hills it forms the main ridge. Below it comes a zone of uneven thickness, usually measuring about 700 feet, which in some portions of the hills is composed almost entirely of fine inky-blue clay, and in others of clay and sand interbedded in varying proportions. Toward the base of this zone, usually between 700 and 900 feet below the top of the formation, there is a zone of fossiliferous sandstone beds equivalent to the zone of *Pecten coalingaensis* occurring in the Kreyenhagen Hills. The beds at this horizon likewise show a tendency to form hills or knobs, but these are not so prominent as those of the upper *Mya* zone.

Below this the formation is largely sand and clay, chiefly sand, down to the base, the lower portion here, as elsewhere, being composed of beds of ordinary sand alternating with beds of blue sand. The next prominent fossil bed contains *Mya* in large quantities, and will be referred to as the lower *Mya* bed. It occurs between very prominent beds of blue sand on the summits of hills; and in the north-central portion of the Kettleman Hills forms the main ridge. Owing to the fact that the formation is thicker in the southern than in the northern portion of the hills and apparently thicker on the western than on the eastern flank of the anticline, the distance below the summit of the formation at which this and other beds occur can not be stated as a constant. The variation of this zone is between about 1,900 and 2,400 feet below the summit. One of the fossils most in evidence in the Kettleman Hills is the large *Mulinia;* a bed containing abundant specimens of this species occurs about 100 feet below the lower *Mya* bed. It is the highest horizon at which the large specimens have been found, and is with little doubt the upper *Mulinia* zone of Kreyenhagen Hills. In the northern portion of Kettleman Hills it is near the base of the exposed series, and is the lowermost easily recognizable zone; in the central portion of the hills it still persists, but lies above exposed beds of considerable thickness. Another zone in which *Mulinia* occurs very abundantly in Kettleman Hills is between 500 and 700 feet below the upper one, and may be referred to as the *Glycymeris* bed, for the reason that it contains an association of fossils, including *Mytiloconcha*, *Glycymeris*, etc., similar to the bed so named north of Coalinga. It is about the lowest bed exposed, and is approximately at the base of the Etchegoin formation.

The following sections represent fairly well the lithologic character and variations of the Etchegoin in the Kettleman Hills. Variability is the rule, and it would be difficult to find any two sections in which the same beds are exposed and the characteristics are constant:

Section of Etchegoin formation on southwest flank of Kettleman Hills, along road 6 miles from northwest end of hills.

	Feet.
Yellowish-gray sand and clay, with some dark clay; many fragments of porcelain shale on surface; small oysters in sand at top, and yellow calcareous shale lenses in bluish-black clay at base; upper *Mya* zone	125
Alternating beds of fine drab gypsiferous sand, sandy clay, and drab to bluish clay, with occasional sandstone layers, and with a bed at the base containing delicate fossils, *Nucula*, etc	250
Similar beds, with layers of iron-stained sandstone at base	115
Similar gypsiferous beds, with light-colored sand predominating; the *Pecten coalingaensis* zone should be here somewhere, but was not found	250
Inky-blue clay with minor beds of sand and with a hard 1-foot bed of yellow limestone in middle	290
Fine sand and some light and dark clay, with hard, very gypsiferous, yellow and variegated sandstone at the top, and interspersed hard layers below; sandstone with *Solen*, etc., near base	135
Highest blue-sand bed	45
Grayish-blue massive sand and pebbly sand, with fossils	130
Thinly and massively bedded drab and light-gray sand with occasional beds of blue sand and layers of inky-blue clay, white clay, and pebbles; the sand at base is the lower *Mya* bed	550
Massive beds of blue and gray sand, with *Mulinia*, etc., at base; upper *Mulinia* zone	100
Less prominent beds of blue and gray sand with sand dollars, oysters, etc	300
	2, 300

On the northeastern flank of the anticline in this same portion of the hills the beds are repeated with approximately the same thickness, but the section measured made it appear that there was possibly a slight thinning on that side.

The next section is on the southwestern flank of the anticline in the south-central portion of the hills, beginning at the 1,030-foot hill on the main ridge in the center of sec. 3, T. 23 S., R. 18 E., and extending northeastward across the strike of the beds to the anticlinal axis.

Section of Etchegoin formation on southwest flank of Coalinga anticline in central portion of Kettleman Hills.

	Feet.
Inky-blue clay below fresh-water bed	50
Yellow and gray sand, full of fragments or nodules of porcelain shale and of fossils, *Mya*, *Macoma*, *Solen*, *Ostrea*, *Arca*, *Littorina*, etc.; the upper *Mya* beds	200
Inky-blue clay zone; sandy beds at top containing innumerable small oysters; occasional layers of yellow calcareous shale; a thin bed, 15 feet above base, of coarse purple and yellow, iron-stained, and exceedingly gypsiferous sandstone with many fossils, probably the *Pecten coalingaensis* zone	725

	Feet.
Mostly light-gray and drab sand, with beds of dark clay in minor amount; a pebbly sand layer 200 feet below top; pebbly sand and iron-hardened sandstone layers near base	1,400
Blue-sand zone, several massive beds of blue sand and pebbly sand interbedded with fine light-gray and drab sand, sandy shale, and pebbly sand and occasional iron-hardened beds; at top is probably the upper *Mulinia* zone; the basal sand is full of fossils, *Mulinia*, *Mytiloconcha*, *Glycymeris*, etc., and is the lower *Mulinia* zone	675
	3,050

As may be inferred from an examination of these two sections, the anticline plunges from the locality of the second toward that of the first, and a much greater thickness of beds is exposed in the second. The upper *Mulinia* zone occurs 2,000 feet below the summit in the first, whereas the bed that has been correlated with it in the second occurs over 300 feet lower. It seems probable from this and similar instances in other sections that the formation thickens toward the south between the top and this bed, the thickening being similar to that which takes place between the oil field north of Coalinga and Kreyenhagen hills. It may reasonably be assumed that a thickening takes place also below the upper *Mulinia* zone, and that the base of the formation is not so far below this zone in the northern portion of the hills as farther south.

Toward the northern end of the hills, as shown by the map, the Etchegoin plunges completely beneath the Paso Robles formation and does not appear again until brought up by the oppositely plunging anticline on Anticline Ridge. Toward the southern end of the hills the formation becomes covered more and more by surface sand and soil, and both its zones and structure are obscured. At the southern end of the hills it does not pass below the Paso Robles, but exposes beds not far above the base.

Importance with relation to oil.—Nowhere within the Coalinga district is the Etchegoin formation known to contain any petroleum, but, like the Jacalitos, it has an important relation to the question of accessibility of the oil. Some wells in the Coalinga field pass through a considerable portion or the whole of this formation before reaching the Jacalitos or lower formations. All wells drilled around the edge of Pleasant Valley, or on Anticline Ridge, or in the Kettleman Hills, will have to pass through this formation, and its thickness must be taken into account in calculating the depth of the oil sands. The great increase in thickness that takes place in this and the other post-Eocene formations south of Waltham Creek has an all-important bearing on such calculations.

PASO ROBLES FORMATION (PLIOCENE-LOWER PLEISTOCENE).

Definition and general description.—The Etchegoin is overlain along the border of the valley by a thick terrane of beds of gravel, sand, clay, sandstone, conglomerate, and some limestone that forms the uppermost member of the series of upturned formations exposed in the monocline on the eastern flank of the Diablo Range. It differs materially from the formations so far described in that its origin is doubtful, being in part fresh water, in part marine, and in large part probably of subærial origin. In the Kettleman Hills, where these beds are best exposed, the basal sand, which appears to lie conformably upon the marine bed at the top of the Etchegoin, contains many fresh-water fossils. The beds above this have a thickness of several thousand feet, and as far as observed are unfossiliferous except at one horizon near the summit at which a few marine fossils have been found. Along the foothills of the Diablo Range in the Coalinga district the basal fresh-water beds have not been recognized and may be lacking. Gravel and sand beds belonging to the same series overlie the Etchegoin with local appearances of unconformity.

This whole series of tilted beds overlying the Etchegoin is referred to here and mapped as one formation, the Paso Robles, for the reason that it appears to be a continuous succession and can not be consistently subdivided in different regions. It was formed without doubt under varying conditions of deposition, but it may or may not represent a continuous period. It began to be formed in some portion (probably the earlier portion) of the Pliocene epoch, and probably represents a continuation of deposition well into the Pleistocene. Its summit may be considered as the highest bed markedly affected by the great uplift that took place early in Pleistocene time throughout the Coast Range region, and as unconformably overlain by the more recent horizontal terrace deposits and alluvium.

The highest portion of the formation exposed appears near the edge of Kettleman Plain in the south-central part of the Kettleman Hills, but the summit of the formation as above defined is not exposed. It is probable that the edge of the hills there marks the approximate summit of the tilted beds. The formation may be recognized most easily by the fresh-water fossils and strange bone beds at its base, by its position overlying all the other formations and bordering the valley, and by the prevalence in it of prominent beds of bowlder gravel, which is much coarser and more abundant than in any of the other Tertiary formations. Otherwise this formation resembles some of the others closely, and it is frequently difficult to differentiate them.

This formation is called Paso Robles, because it is the same as the formation which spreads over the summit of the Temblor Range south of Polonio Pass, the divide between the Antelope and Cholame valleys, and from there southward to the Palo Prieto Pass, and which may be traced thence to Paso Robles in the Salinas Valley, where it was named by H. W. Fairbanks.[a]

The formation in the type locality consists of a thickness of at least 1,000 feet of slightly coherent conglomerate, gravel, sand, and clay in stratified deposits that have been locally tilted to moderate angles and that lie unconformably upon the marine Pliocene and older formations. The formation is unfossiliferous and is believed by Fairbanks to be of fresh-water origin.

Kettleman Hills.—The Paso Robles is completely exposed only in the Kettleman Hills, and its occurrence there forms the basis for most of the discussion given here. As shown on the map it occupies an almost complete fringe around the hills, dipping steeply away on the flanks of the anticline which exposes the Etchegoin beneath. Throughout the Kettleman Hills the Etchegoin and Paso Robles are apparently conformable, and in places, especially toward the northern end of the hills, there are indications that a gradual change took place toward the end of the deposition of the former, that shallow-water marine conditions gave way to brackish-water and this in turn to fresh-water conditions. The upper *Mya* beds are constant at the top of the Etchegoin and contain a fauna that with the possible exception of one species, *Littorina*, is indicative of estuarine conditions. And these beds, in some places at least, grade into the fresh-water beds above.

The thickness of the basal fossiliferous zone of the Paso Robles is usually no more than 60 to 100 feet, although it is as much as 300 feet on the southeastern side of the Kettleman Hills a few miles northeast of Avenal Gap. The beds consist principally of fine-grained earthy sand, very gypsiferous, and frequently containing many scattered pebbles. The fossils are entirely fresh-water forms and occur in places very thickly embedded. Along a part of the northeastern side of the hills certain layers are so indurated as to form hard limestone and to produce a ridge marking the contact between the Etchegoin and the Paso Robles formations. Associated with the fresh-water beds are abundant small bones that have not been identified. They are characteristic of this zone, but have been found also in association with marine fossils in a bed many hundred feet below the top of the Etchegoin. The only fossils found in the Paso Robles at a higher horizon than the basal zone are noted in the second tabular section below (p. 59). A few good specimens of these and many fragments were found in two beds of coarse pebbly sand 15 feet apart in the upper portion of the formation.

Above the basal zone the formation consists of a continuous unvaried succession of alternating zones and beds of unconsolidated light-gray

[a] Geologic Atlas U. S., San Luis folio (No. 101), U. S. Geol. Survey, 1904.

and yellowish fine sand, sandy clay, light and dark clay, coarse darker gray sand, and gravel and bowlder beds, and occasionally interbedded layers of hard sandstone. The whole series is gypsiferous. The beds are usually fairly thick and massive and the bedding planes not very pronounced, although in some places the strata are sharp and square cut. Frequently the stratification and the dip appear more distinct from a distance than from near at hand. Many of the coarse sand and gravel deposits are roughly stratified and exhibit lenticular structure, grading within a short distance into finer deposits. In general, the formation resembles very closely the recent alluvial deposits and is almost indistinguishable from them except by means of the disturbed position of its beds.

A marked feature of the gravel is the predominance in it of subangular fragments of hard white siliceous shale, derived presumably from the shale either of the Tejon or of the Santa Margarita. This shale is very resistant and lends itself remarkably to preservation in younger deposits of gravel and débris. The other pebbles and bowlders in the gravel beds of the Paso Robles are of many different Coast Range types of rock and have probably been derived chiefly from the Diablo Range. Many of them are angular and have been subjected to little wear before being deposited. Rocks of a granitic type are very common, and the area also contains serpentine, porphyries of different kinds, different varieties of basic igneous rocks, both fresh and considerably altered, jasper, sandstone, conglomerate, quartz, schist, etc.

The lower beds of the Paso Robles in the Kettleman Hills are as a rule not of very coarse material, although pebbles are scattered through them. The first important zone of coarse gravel appears several hundred feet above the base. It is associated with several beds of hard sandstone, and in consequence shows a marked influence on the topography, forming a hill on each of the lateral ridges descending from the summit to the valley. This zone probably occurs at a slightly variable horizon, ranging from about 500 to 800 feet above the base of the formation. It is in general higher toward the south in the hills, and may thus indicate a thickening of the formation in that direction. Above this zone occur various other prominent gravel zones.

The following columnar sections represent fairly well the character of the formation in that part of the Coalinga district in which it is most completely exposed. In each place the section was started at the edge of Kettleman Hills, but beds were not found exposed for about 700 feet into the hills away from the edge. In this border area the beds almost certainly have a fairly steep dip, and it would be conservative to add at least 150 feet to the total thickness given to represent the summit beds there.

The first section was made on the southwest side of the hills, about 9 miles northwest of Avenal Gap, and is as follows:

Section of Paso Robles formation 9 miles northwest of Avenal Gap.

	Feet.
Mostly fine, earthy, drab and yellowish-gray, faintly bedded massive sand, with occasional roughly aggregated beds and lenses of pebbles and bowlders; the stratification bedding is very apparent from a distance	500
Similar beds of hard and compact straw-colored massive sandy clay, with partings of gypsiferous sandstone	300
Similar clay interbedded with pure sand, gravelly sand, and sandstone layers, with a hard sandstone bed at base	75
Compact, drab, gray, and straw-colored coarse and fine sand	200
Thin layers of gravel and coarse sands, with a bowlder bed several feet thick at base	75
Pure fine sand similar to that above, with hard sandstone layers	125
Mostly gravel, composed in large part of fragments of hard, white, siliceous shale, interbedded with sand and sandy clay, and with hard sandstone beds at top and base	75
Alternating beds, from a few inches to 1 or 2 feet thick, of loose and compact fine sand, roughly bedded slightly gritty clay, pebbly sand, gravel, and hard usually purplish sandstone; some of the sand is speckled all over with inclusions of hard, white siliceous shale, and the gravel is largely composed of it	225
Pure clay and sandy clay	75
Fine clay and sand at top, grading down to coarse sand and pebble and bowlder beds at base; some fine drab sand forms hard, massive, roughly laminated beds	75
Drab sand with some pebbles and with gravel and hard sandstone beds at base	150
Sand and clay and a few hard sandstone beds	375
Gravelly sand	100
Loose earthy sand full of pebbles, bowlders, and fragments of white siliceous shale, and containing fresh-water shells, and bones; at the base is a sharp change to the dark clay and upper *Mya* beds of the Etchegoin	50
	2,400

The following section was made on the southwestern flank of the Kettleman Hills, along the Dudley-Lemoore road, which crosses about 4 miles northwest of Avenal Gap:

Section of Paso Robles formation along Dudley-Lemoore road.

	Feet.
Massive 1- to 3-foot beds of well-compacted but not indurated fine sand, clayey sand, clay, coarse sand, and gravelly sand, with several beds, many feet thick, of coarse gravels and bowlders in the middle and at the base. Much gypsum occurs in fine particles and as a filling in cracks, causing hardening in individual beds and in spots. Some sand and gravel beds are lenticular. One hundred feet below top are two coarse sand beds, 15 feet apart, containing *Ostrea* and *Littorina*, marine fossils	400
Yellowish-gray earthy sand, sandy clay, and clay in well-defined massive beds with some pebbly sand	650
Dark clay	75
Thick zone of pebbly sand	150
Chiefly dark clay	150
Yellowish-gray fine sand yielding whitish surface sand	75
Pebbly sand	70

	Feet.
Sandy clay	80
Chiefly fine gray sand, alternating with pebbly sand, sandy clay, and clay; a thick zone of pebbles and bowlders occurs about 350 feet below the top	1, 100
Chiefly fine gypsiferous ashlike light-gray sand, with dark clay layers and many large pebbles scattered through, but no prominent gravel beds; lower portion is the fossiliferous fresh-water zone, but no fossils were here found; it overlies dark clay and *Mya* beds at the top of the Etchegoin	350
	3, 100

Kreyenhagen and Jacalitos hills.—The Paso Robles beds dip under the Kettleman Plain and reappear on the western arm of the syncline along the border of the Kreyenhagen and Jacalitos hills. As in the Kettleman Hills, the formation dips more steeply and exposes a much greater thickness toward the south, but here this difference is even more pronounced. The beds have a dip of only a few degrees northwest of Zapato Creek and form a comparatively narrow belt to where they are finally overlapped by the alluvial deposits of Pleasant Valley. South of Canoas Creek the Paso Robles beds rise to extremely steep dips, appearing almost overturned in places, and cover a wide belt. They are, however, very poorly exposed. The formation here consists of deposits similar to those in the Kettleman Hills, but the basal fossiliferous beds have not been found. The formation is chiefly characterized by its heavy gravel deposits, which, contrary to the rule in the Kettleman Hills, in places rests directly upon the Etchegoin, forming high hills fronting the valley. This occurrence of heavy bowlder deposits near the base has led to the theory that possibly the fresh-water basal zone is lacking and that a higher portion of the Paso Robles has overlapped upon the Etchegoin. Northwest of Zapato Creek a distinct unconformity between the Paso Robles and the Etchegoin is shown to exist by the fact that the gravel beds of the former overlap upon the Etchegoin and locally cover up some of the higher beds of that formation. Southeast of Big Tar Canyon the basal portion of the Paso Robles is sand and clay and is marked by a zone of white nodular shale beds, interbedded with sand, containing the strange bones mentioned before as occurring in the fresh-water beds in the Kettleman Hills. The Etchegoin and Paso Robles appear conformable in the southern part of the Kreyenhagen Hills. The latter has a thickness of at least 2,000 feet and probably much more.

Guijarral Hills.—In the northern part of the Coalinga district the Paso Robles is doubtless continuous beneath the valley floor but does not appear exposed except in the Guijarral Hills, which are entirely covered by deposits of coarse gravel of this formation, the name of the hills being derived from this feature. The beds are almost horizontal but appear to dip slightly toward Pleasant Valley and Polvadero Gap, giving the surface of the hills the appearance of a plane inclined in those directions. The beds are exposed by the Coalinga anticline and probably belong in the lower middle portion of the formation. They may be traced northward on the east flank of Anticline Ridge, but are throughout this region poorly exposed. The contact with the underlying Etchegoin can not be definitely traced nor the relations of the two formations determined.

Importance with relation to petroleum.—The Paso Robles formation does not come in contact with the oil-bearing formations and contains no traces of oil. Over most of the area in which it occurs it is separated by so great a thickness of deposits from the productive zones that its mere presence is usually sufficient to indicate the inaccessibility of the oil. Around the border of Pleasant Valley and on Anticline Ridge and the Guijarral Hills, however, productive wells may later be put down through this formation.

TERRACE DEPOSITS AND ALLUVIUM.

The later Pleistocene and recent periods are represented by a mantle of alluvium and terrace deposits covering the floor of the Great Valley and the large side valleys, and extending over the bottom of most of the smaller valleys and canyons and the lower slopes of the foothills. The larger areas of these deposits are shown on the map (Pl. I, in pocket) in white. In the large valleys it is probable that these deposits have a thickness of several hundred feet, as the late period has been largely one of aggradation. Elsewhere the deposits are merely superficial. All of the smaller valleys show evidences of several terraces along their sides, these being especially evident along Zapato Creek, where at least seven terraces may be counted. Many of these terraces are covered with stream gravel and sand. The greater portion of the whole region under discussion is covered by surface soil and residual sand derived from the soft formations. All of these comparatively recent deposits are similar in materials and appearance to the underlying formations and are not easily distinguishable from them. They have the effect of obscuring the main facts of the geology over large areas.

IGNEOUS ROCKS.

The only igneous rocks occurring within the Coalinga district are associated with the Franciscan formation. The Cretaceous, Tertiary, and Quaternary formations were not affected by igneous intrusions, and there is no evidence that there was volcanic activity in this or the adjacent regions during these periods. The serpentine that has already been mentioned as covering such a wide region in the heart of the Diablo Range originated as an intrusion of basic igneous rock into the Franciscan sedimentary formation before the beginning of the period in which the Knoxville and Chico formations were laid down. Many different varieties of it occur, varying from hard, little-altered peridotite, in which the constituent crystals are well displayed, to much-metamorphosed and surficially altered serpentine and related minerals.

Toward the head of White Creek a hill formed of a hard hornblende-bearing igneous rock seems to have been intrusive into the serpentine. It is a soda-bearing syenite, of a variety heretofore undescribed, and varies from an extremely fine-grained to a porphyritic facies in which there are large, perfect crystals of hornblende. The area of this rock as shown on the map is slightly exaggerated in size.

STRUCTURE.

Some of the broad features of the structure of the Coalinga district have been briefly touched on in the preceding discussions of the topography and geology. The structural axes and the general attitude and succession of the strata are outlined on the map (Pl. II), and therefore merely a general review of the whole and the discussion of certain particular points is necessary here.

CROSS STRUCTURES AND THEIR TOPOGRAPHIC INFLUENCE.

The structure of the Diablo Range is, broadly speaking, anticlinal, and its eastern flank is composed of a great monocline of sedimentary strata dipping toward the San Joaquin Valley. But the regularity of this monocline is broken by its being thrown into a series of waves and offsets by various important as well as minor plunging anticlinal and synclinal folds, and by faults that run in various directions both parallel with and oblique to the main structural trend of the mountains. This main trend parallels the general course of the Sierra Nevada, the Coast Ranges, and the coast in this portion of California, and is approximately N. 35° W. to N. 40° W. The general orientation of the secondary structural axes is considerably more to the west of north than this. These show their influence prominently in the topography by producing the oblique spurs and valleys discussed under the subject of the topography. The same features, both topographic and structural, may be observed south of the Coalinga district and also in the mountainous tracts west of it. It is due to such structures that the Gabilan Range converges and joins with the Diablo Range in the latitude of the Coalinga district; and the various discontinuous spurs of the high and complex portion of the Diablo Range, which are arranged in positions en échelon with one another, may be explained on the same basis. It would appear therefore that the region has been subjected to two main sets of compressional forces, the one set acting on a line running roughly

N. 50° E. and the other set being along a line running N. 20° to 30° E., making a counter-clockwise angle toward the north of about 20° to 30° with the former set.

PERIODS OF MOVEMENT AND THE EFFECT ON FORMATIONS OF DIFFERENT AGES.

A large part, if not the major part, of the movement that has resulted in the disturbance of the Tertiary beds in this region, and of the Cretaceous beds over considerable areas in which they were not previously greatly disturbed, took place in Pleistocene time after the deposition of the Paso Robles (Pliocene-Pleistocene) formation. This feature of the history of the region is indicated by the fact that the later Tertiary and early Pleistocene formations appear to have been disturbed almost as much as the older ones, and in some places as much as the Cretaceous beds. An example of this is found in the beds exposed in the Coalinga anticline, which dip gently and would hardly appear to have been folded at all previous to the time in which the Etchegoin (Pliocene) beds were tilted on the same anticline to the vertical position. It is certain that important movements were taking place during Cretaceous and Tertiary time, notably at the close of the Tejon (Eocene) period of deposition, when the beds of that age were uplifted and greatly disturbed before the subsidence that allowed the deposition of the Vaqueros (lower Miocene) beds on their eroded surface, and also at the close of the Vaqueros period. The fact that all the formations from the Cretaceous to the lower Pleistocene appear in places to be conformable in dip, and that at least the Miocene, Pliocene, and later deposits almost invariably appear so, indicates that the whole series was affected as one during the Pleistocene by extraordinarily severe disturbances.

In the Tertiary formations the land movements have resulted chiefly in folding rather than in faulting. The strata of these formations are everywhere tilted at angles ranging from a few degrees to the vertical and are locally overturned, but evidences of faulting are by no means as frequent. The older formations, on the other hand, are much faulted as well as folded, and many faults occur in them that have not been mapped. The Knoxville-Chico (Cretaceous) rocks exposed along Los Gatos Creek afford an excellent example of the very great number of large and small faults occurring along a fault zone such as that which determines the position of this old valley.

It has been pointed out in the description of the formations how they vary in thickness within short distances. This variability is a characteristic feature of the geology of the region. In the post-Eocene formations it may be explained on the theory that the gradual subsidence which took place during the different periods progressed more rapidly toward the south than it did in the northern part of the Coalinga district, where the shore line must have been near, and that the periods of land conditions interrupting the progress of sedimentation were more prolonged and frequent in the northern region.

The number of mutually unconformable formations present in the Coalinga district proves that the region was undergoing almost continuous movements. The unconformities are rarely very apparent at the contact between the formations, and the fact of the existence of unconformable relations is usually to be made out only from a detailed study (1) of the areal distribution of the formations, which gives a clue to the presence of overlaps, and (2) of the fossils, which indicate time breaks. The evident angular unconformities are between the Vaqueros (lower Miocene) and Tejon (Eocene) at various localities, between the Tejon and the older Cretaceous shale at points on Reef Ridge, between the Vaqueros and Cretaceous in the Alcalde Hills and on Juniper Ridge, between the Santa Margarita (upper middle Miocene) and Vaqueros where the Castle Mountain fault zone crosses Reef Ridge; between the Santa Margarita and Tejon at the same point and also at the San Joaquin coal mine, and between the Santa Margarita and Cretaceous along the north and east sides of McLure Valley. Somewhat more doubtful is the apparent discrepancy between the Paso Robles (Pliocene-Pleistocene) and Etchegoin (upper Miocene) north of Zapato Creek. Elsewhere the formations, even those profoundly distinct in age, generally appear conformable in dip.

Overlaps of all of the Tertiary formations, except the Paso Robles, upon the Cretaceous occur within the Coalinga district, thus proving their mutual unconformity. Except in the overlap of the Etchegoin on White Creek and of the Vaqueros in the Alcalde Hills over the upper Cretaceous (Chico) sandstone these overlaps take place over the lower portion of the rocks mapped as Knoxville-Chico. The variability of the formations in original areal extent and in thickness, lithologic character, and structure within small areas gives an indication of the local activity of the disturbing forces which have continued to act within this region.

MAIN LINES OF STRUCTURE.

Coalinga anticline and syncline.—Among the individual features of the structure in the Coalinga district the Coalinga anticline is next in importance to the general monocline on the eastern face of the Diablo Range. This anticline is one of the principal oblique structures of the range. It forms Joaquin Ridge and plunges toward the valley, exposing in turn the Franciscan formation at the head of

Joaquin Ridge and all of the subsequent formations. The synclinal axis of its plunge occurs at Polvadero Gap, beyond which it is undoubtedly continued by the anticline plunging in the opposite direction, which causes the beds to dome up into the Kettleman Hills. At the southern end of these hills, about a mile south of the area mapped, the anticline does not plunge beneath the surface of the valley again as might be expected by analogy. On the contrary, it exposes a fairly low portion of the Etchegoin formation and the hills are left incomplete, their cessation being due to erosional removal rather than to structure, as at the northern end. The Lost Hills, which are situated within 10 miles south of the edge of the area shown on the map, have not as yet been studied, but it is a probable supposition that they are due to a continuation of the Coalinga anticline. The length of this within the district is 60 miles. Its principal features are its alternating plunges in different directions; its curving course, indicating a complexity in the forces which have acted upon it; its asymmetry, and its broad summit and steep flanks. The steep dips on its southwestern flank north of Coalinga, as compared with the gently dipping summit and northeastern flank, are very pronounced. Similar asymmetry is observable in the northern part of the Kettleman Hills, although the divergence in dip on the two flanks is not so great, the usual maximum dip being 35° to 45° on the southwest and 25° to 31° on the northeast. The Coalinga syncline is the parallel supplementary feature and forms the topographic depression of Pleasant Valley and Kettleman Plain. Like the anticline, it plunges southeastward from Joaquin Ridge and rises again opposite the Kettleman Hills. West of Oil City it dies out in low dips on the flank of the anticline.

The folds and faults forming the other main spurs of the Diablo Range in this district have already been mentioned in the discussion of the topography.

Los Gatos and White Creek basins.—The structure in the basin of Los Gatos and White creeks between Joaquin and Juniper ridges is peculiar and complicated. A broadly folded anticline of Cretaceous beds with a locally sharp axis plunges southwest and northeast off the flanks of these two ridges toward the lower part of Los Gatos Creek, where it is crossed by a broad syncline plunging both northwestward into the axis of the White Creek basin and southeastward into Pleasant Valley. The syncline becomes sharply defined and regular along White Creek where it incloses a remnant of Etchegoin. Toward Pleasant Valley it broadens out to form part of the general monocline dipping toward the axis of the Coalinga syncline. A complicated set of faults occurs along Los Gatos Creek, where the upper sandstone of the Cretaceous (Chico) near the axis of the syncline on its southwestern side is faulted down into contact with the older Cretaceous shale beds on the southwest side of the main fault line. The movement has been in the nature of a flattening of the axis of the syncline toward its head, resulting in the formation of branch faults on the downthrow side and greater and greater throw in the successive blocks toward the southeast. Many small faults occur that have not been shown on the map, and there are doubtless other large ones that have not been observed. The basin of Los Gatos and White creeks has probably been an axis of movement along which successive disturbances have taken place during a long period.

Alcalde Canyon.—Another old zone of movement is represented by the southeastern face of Curry Mountain and the lower part of Alcalde Canyon from Alcalde toward Pleasant Valley, and possibly likewise out across the valley toward Polvadero Gap. The region north of this zone has had in some respects a different history from that to the south, and it is difficult to correlate the features of the geology in the regions so separated. To the south the formations have a far greater thickness, the upper sandstone (Chico) portion of the Knoxville-Chico rocks is lacking, the shales of the Santa Margarita(?) appear and gradually thicken and are only doubtfully to be correlated with the Santa Margarita formation to the north, and a great thickening of the Paso Robles formation is steeply tilted and well exposed.

Jacalitos Hills.—Between Alcalde and Reef Ridge there is a depressed area occupied by comparatively low, rolling hills that represents the structural continuation of the old synclinal basin of Waltham Valley. The syncline of that valley plunges toward the southeast and dies out just within the area mapped on the general monocline dipping away from Reef Ridge. This monocline is regular except for some low, broad, plunging folds that throw it into undulations northwest of Zapato Creek, among them being the Jacalitos anticline and syncline. A noteworthy feature of the Jacalitos anticline is that it plunges in both directions into the flank of the Jacalitos syncline.

Castle Mountain fault zone.—The main structural features of the southwestern part of the territory mapped are the Castle Mountain fault zone, Pyramid Hills anticline, Avenal syncline, and Diablo anticline. The Castle Mountain is a very important and complicated zone of faulting that affected the Vaqueros and older formations. The downthrown side is on the northeast. Faulting along the same zone is the cause of the prominent scarp of Castle Mountain, farther west. Within the area mapped the movement took place probably before the beginning of Tertiary time, leaving the fault scarp as the shore line during the Tejon (Eocene) and Vaqueros (lower Miocene) epochs. The fault is not exposed east of Reef Ridge because covered by the later formations. The lowest of these, the Santa Margarita, is only very slightly wrinkled at this point, showing that practically all movement along this part of the Castle Mountain fault ceased before the upper Middle Miocene.

Pyramid Hills anticline.—The Castle Mountain fault zone is the locus of an important anticlinal fold that was formed during the Pleistocene long after the cessation of fault movement along the eastern portion of the zone. The Santa Margarita and younger formations have been worn off over the summit of the fold and the rocks exposed along this uncovered axis belong in part to the Knoxville-Chico, but some strange varieties differing from any observed elsewhere occur and have not been identified as belonging to any known formation. The disturbance of the pre-Santa Margarita rocks has been so great that the axis of the anticline is not easily traceable within the faulted zone. To the southeast the general zone of faulting gives place along a divergent axis to an overturned anticline in the Knoxville-Chico rocks, and this is traceable into a regular, sharp fold covered by the shale of the Santa Margarita. This is the anticline forming the prominent ridge of the Pyramid Hills and the northeastward-tilted monocline of Reef Ridge and the Kreyenhagen Hills.

Avenal syncline.—On its southwest flank the Pyramid Hills anticline dips down into the Avenal syncline, which determines the position of McLure Valley. North of Avenal Creek this syncline is an extremely sharp fold, overturned and much disturbed beyond the area mapped, but gradually plunging and becoming shallower toward McLure Valley.

Diablo anticline.—Southwest of the valley the beds rise again steeply on the flank of the Diablo anticline, which is a steep fold plunging rapidly toward the southeast and forming Avenal Ridge, the end of the Diablo Range. Its axis was once overarched by the Santa Margarita and later formations, but is now denuded of these formations and exposes greatly disturbed Knoxville-Chico rocks. This anticline is one of the main axial folds of the Diablo Range.

CHARACTER OF THE FOLDS AND FAULTS.

The structural features in this region are almost invariably plunging and curving. Most of them represent important and continuous structural lines along which movements of locally variable amount and direction have taken place. The anticlines are as a rule asymmetric elongated domes, the summits being broad and the dips increasingly steep away from the axis, but having varying limits of angle on the two sides and at different points along the longitudinal extent of the fold. The synclines have a reciprocal character. Several of the anticlines, notably the Coalinga, Jacalitos, and Pyramid Hills anticlines, are so formed that an axis may be traced on one or the other flank along which is a marked steepening of the dip away from the summit of the fold. This indicates an inclined position for the main axis of the fold. An overturn occurs in the inclined axis of the Coalinga anticline at one point along Oil Canyon, and overturns occur likewise along the Pyramid Hills anticline, the Avenal syncline, and on the northeastern flank of the Diablo anticline. An important feature of the structure of the district is that the northern portion of the axis of the Coalinga anticline and the axis of the Jacalitos anticline lean toward each other, the former toward the southwest and the latter toward the northeast, as if due to a compressional force from the two sides toward the Coalinga syncline. The Pyramid Hills anticline is analogous in this respect to the Coalinga anticline northeast of Pleasant Valley, and seems to be opposed in a similar way across McLure Valley by a contrary thrust in the Diablo anticline. The two latter folds have, however, not been studied in detail.

In regard to the character of the faults in this region little can be said, owing to the fact that the areas of older rocks in which they chiefly occur were examined only in a reconnaissance way. In the case of the Los Gatos Creek and Castle Mountain fault zones the planes of movement have been many and the resultant downthrow in each case is on the northeast.

THE OIL.

OCCURRENCE.

The petroleum in the Coalinga district occurs in four different formations, the Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (upper middle Miocene), and Jacalitos (upper Miocene). In the first the oil is thought to be primary—that is, it is believed to have originated in the formation; in all of the others it is secondary—that is, it has come into them from some outside source since their formation.

OIL ZONES.

Geologic position.—Within each of the formations are one or more oil-bearing zones, consisting either of more or less extensive layers of sand or gravel, which can be traced in a general way over large areas, or of local lenses of the same materials. The oil sands in the Tejon (Eocene) will be referred to collectively as the Tejon oil zone; those in the lower part of the Vaqueros as the lowest Vaqueros zone, or zone D; those in the middle Vaqueros (Eastside field light-oil sands) as the light-oil zone, or zone C; those in the upper Vaqueros (first sand) in the fields northeast of Los Gatos Creek and in the lower Jacalitos in the Westside field south of Los Gatos Creek as zone B;

and those in the Jacalitos in the Westside field above the productive basal beds of that formation as zone A. The top of zone B is shown in contour on Pl. II. With the exception of those in the lowest zone in the Vaqueros (zone D) the oil sands are known to consist in many places of more or less local beds or lenses showing abrupt differences in thickness, composition, grain, and hardness from well to well, often with a puzzling diversity in gravity of product within short distances. Zone D, as would be expected of the basal portion of a widely spread formation, partakes of the same general characteristics throughout nearly its entire range within the district—that is, it is usually coarse gravel at the base, with somewhat finer gravel or very coarse sand above this, and finally medium-grained sand. The productive beds in the other zones vary from medium fine-grained to coarse pebbly sand or even gravel.

Tejon oil zone.—The sandstones underlying the shale of the Tejon (Eocene) formation or interbedded with its basal members contain commercial quantities of oil on the Coalinga anticline in the Oil City field, and also at several points on the flanks of the great steep-dipping monocline in the Kreyenhagen field. Many oil seepages occur along the outcrops of these sands, and it was the inducement offered by these seepages in the Oil City region that led to the drilling of the test wells from which the present district has been developed. The oil in the Tejon is usually of light gravity, about 33° to 34° B., and greenish in color. The thickness of the productive sands is ordinarily between 15 and 60 feet, and the yields are light, 4 to 75 barrels per well per day being the normal extremes of production, although the initial flow of one of the Oil City wells is said to have been 700 barrels per day.

Vaqueros oil zones.—The principal oil-bearing formation in the Coalinga district is the Vaqueros or lower Miocene. It yields practically all of the oil in the Eastside field, a considerable part of that from the Westside field, and is thought to contain commercially important quantities in the Kreyenhagen field and in the region of the Kettleman Hills. The total distance penetrated through this formation by the wells in the Eastside field is about 700 feet, and in the Westside between 300 and 500 feet. The actual productive sands of course occupy only a relatively small space in this column, usually less than 150 feet in the Eastside and less than 100 feet in the Westside. Three zones are recognized in this formation, the lowest, or zone D, the middle, or zone C (productive only in certain parts of the Eastside field, where it yields oil up to 31° B. in gravity), and zone B, recognized as Vaqueros, in the Eastside field and in the northern part of the Westside field. The oil from the Vaqueros varies in gravity from 14° to 22° in the Westside and from 14° to 31° in the Eastside. It is black or dark brown and the production averages between 100 and 200 barrels per well per day. One well in the Eastside field is now flowing 3,000 barrels of oil per day, and an initial yield of 7,000 barrels in eighteen hours was recorded for another well in the same field, but these figures are unusual.

Santa Margarita oil zone.—A stratum of sand carrying characteristic fossils of the Santa Margarita formation immediately overlies the Tejon in the region of the San Joaquin coal mine in the Westside field, but is so closely associated with lithologically similar beds of the Jacalitos in the same vicinity that it has been mapped and discussed with them as zone B. The persistent stratum of fine blue sandy shale found throughout the Eastside field and known locally as the "Big Blue," is arbitrarily placed in the Santa Margarita formation. The "Big Blue" immediately overlies the uppermost Vaqueros oil zone, zone B, the top of which is shown in contour on the map (Pl. II).

Jacalitos oil zones (A and B).—The Jacalitos (upper Miocene) formation is productive throughout the Westside field, except at the extreme southern and northern ends and in those wells distant over a mile or so from the outcrop of the sands. In other words, the formation is commercially oil bearing wherever it rests upon or is relatively near to the Tejon formation, the source of the oil.

Two oil zones are recognized in the Jacalitos, the lower, or zone B, which is the productive zone over the southwestern part of the Westside field, and zone A, situated some 200 feet above zone B, which carries tar sands or poorly saturated oil sands. The two zones are generally separated by sulphur water—the "big sulphur"—although the most persistent sulphur water in the northern end of the Westside field overlies zone A. Northward in the Westside field the productive sands of zone B are found lower and lower in the series of beds until in the northern end the oil is believed to come from beds in the uppermost Vaqueros, just below the base of the upper Miocene (either Santa Margarita or Jacalitos).

ACCUMULATION OF THE OIL.

The influence of structure on the accumulation of the petroleum varies somewhat for different parts of the field, the variation being due, it is believed, to the presence or absence of water beneath the oil zones in the various areas. In general the oil in the Tejon (Eocene) is accompanied by water in the underlying beds, and possibly also in the oil sands far down on the dip; under these circumstances the anticlinal theory[a] of accumulation seems to hold good. A modified

[a] The anticlinal theory of oil accumulation assumes that the oil, being of less specific gravity, rises above the water present in porous rocks and collects at the highest possible points in upward folds, being there confined by impervious strata arching over the folds. The presence of water, according to this theory, is considered as fundamentally necessary for the carrying out of the process of accumulation in anticlines. For a fuller discussion of this subject see Arnold, R., and Anderson, R., Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Cal.: Bull. U. S. Geol. Survey No. 322, 1907, pp. 71 et seq.

form of the same theory is apparently applicable to certain monoclines, in which water is associated with oil, such as those in the Westside and Kreyenhagen fields, where, instead of impervious beds overlying the porous sands, the residual tar or heavy hydrocarbons left upon evaporation of the lighter substances originally in the contained petroleum seal the outcrops and hinder or prevent the escape of the oil from below.

Where no water exists in or is associated with an oil zone, as, for instance, in the deeper portions of the Westside field and in by far the greater part of the Eastside field, structure apparently plays but a minor part in the accumulation of the oil, the presence or absence of the petroleum in the porous strata of the zone apparently depending entirely upon the presence or absence of the oil-yielding shales of the Tejon (Eocene) below or near to the beds in question. If the Tejon is present under any particular sand or zone, then the abundance or scarcity of the oil depends largely on (1) the proximity of the particular sand to the Tejon; (2) the state of disturbance of the underlying shale of the Tejon, or its relative position (whether unconformable or conformable) to the overlying beds; (3) the degree of porosity and grain of the sands of the zone; and (4) the effectiveness of the barriers hindering the escape of the hydrocarbons (oil and gas) from the oil sands.

Within the tested territory of the Coalinga district it has been found that the areas of Miocene sediments (either Vaqueros, Santa Margarita, or Jacalitos), immediately underlain by the shales of the Tejon, are oil bearing; that the productiveness of these beds varies roughly inversely with their distance from the Tejon; and that the productiveness is greatest where the Tejon occupies a position of angular unconformity with the Miocene sands or is more or less disturbed, as near the axis of an anticline such as the Coalinga anticline.

GRAVITY OF THE OIL.

The gravity of the petroleum at any point in any particular bed is apparently influenced chiefly by (1) the original composition of the oil; (2) the thickness and composition of the media through which it has migrated and in which it is detained; (3) its present or past association with water; and (4) its present distance from the outcrop of the oil-bearing zone or its depth below the surface, etc. Little definite information is now available concerning the effect of many of these factors. It seems in general, however, that the oil loses in gravity by migration either upward through various strata or along a particular bed; that it loses on association with water; that within certain limits it decreases in gravity up the dip, owing, probably, to proximity to the surface, with its accompanying facilities for the escape of certain of the hydrocarbons; and that, other things being equal, the finer the grain of the containing reservoir the better the oil will retain its original quality.

RELATIONS OF WATER TO OIL.

The most important problem next to that of the actual occurrence of the petroleum in any field is the relation of the water sands to the sands containing the oil. One or more sands carrying water are almost invariably encountered above the Miocene oil zones in the wells of the Coalinga district. The continuity of these sands can seldom be traced far, and they are believed to be for the most part disconnected lenses rather than far-reaching beds. An examination of the surface outcrops leads to the same conclusion. The contents of these upper water sands is believed to be surface or secondary water—that is, water which has percolated into them since they were tilted into their present position and their edges exposed. This secondary water is seldom under much head, although in a few instances it has been known to flow with considerable energy.

One of the most persistent layers or zones of water is the one termed the "Big Sulphur," a malodorous blackish fluid met with in or above zone A in the Westside field north of Los Gatos Creek, and between zones A and B south of Los Gatos Creek. No productive oil sands are found above this sulphur-water sand, although one or more tar sands are sometimes found; it may therefore be considered the limit of the upward migration of the oil, at least in commercial quantities. A similar and fully as persistent zone of sulphur water is encountered immediately above the second oil zone, zone C, over a large part of the Eastside field. The sulphur content of these waters probably bears an intimate relation to the oil, for in all of the seepages in this field where the oil is accompanied by water the latter is heavily charged with sulphur. However, not all of the sulphur springs in the region contain oil, so that there is a possibility of the sulphur even in this particular sand having an origin independent of the petroleum.

In all of the wells in the Westside field in which the Jacalitos or upper Miocene oil zone (zone B) can be recognized the latter is immediately underlain by a stratum of water. For various reasons it is thought that in this case also the water is secondary and has come into the formation since the passage of the oil from the Tejon (Eocene) into the Miocene. With the exception of a very limited area in the Eastside field no water has so far been reported from below the lowest Vaqueros oil zone (zone D), which indicates almost conclusively that water was not the elevating force for the oil of zone D; it also strengthens the conclusion that the water in the higher zones is surface water that has percolated from the outcrops in the local catchment basin, rather than primary water, that has been in the beds since their deposition, or water that has come up from below under hydrostatic pressure.

ORIGIN OF THE OIL.

As to the origin of the oil in the Coalinga district, it can be stated unequivocally that it comes from the shales of the Tejon (Eocene) formation; and it is believed that it is derived from the organic material in them. These shales are composed largely of the tests or shells of diatoms and Foraminifera, and a smaller number of other organisms, in such abundance as to fully warrant the assumption that the animal and vegetable material that must have been contained in them when deposited was adequate for furnishing a quantity of hydrocarbons and other compounds more than equivalent to the quantity of petroleum found in this field. The shales of the Tejon are everywhere petroliferous, their interbedded sands productively so, and wherever overlain by sediments these also are petroliferous. Furthermore, the relative productivity of these overlying beds varies inversely with their distance from the Tejon. If the shales of the Tejon were simply the medium of migration for the oil from below, the shales of the subjacent Knoxville-Chico (Cretaceous) would also be expected to serve as such, for they are lower down stratigraphically and are apparently of proper consistency (clayey shale) for migration by diffusion. We would also expect to find them charged with oil, their interbedded sandstones productive, and the Miocene overlying them containing at least as much, if not more, oil than the same formations overlying the Tejon. But these postulated conditions concerning the Knoxville-Chico (Cretaceous) do not exist. The Cretaceous shales and sands have been examined carefully in outcrop, and wells have been drilled into them in several places, but practically no indications of petroleum were found. The Miocene (Vaqueros, Jacalitos, and Etchegoin) sands overlying the Cretaceous in a position analogous to that of the Miocene overlying the Tejon (Eocene) yield oil only when situated comparatively near the Cretaceous-Eocene contact. This is most significant, indicating that the Cretaceous did not yield the oil, but that the latter, as would be expected, after passing from the Eocene into the Miocene has migrated for a short distance along the strata of the latter out over Cretaceous beds. Other negative evidence pointing to the origin of the oil in the Tejon is presented by the fact that there are no faults of consequence within the productive area along which migrations from depths could have taken place.

THE OIL FIELDS.

SUBDIVISIONS.

For convenience of discussion the Coalinga district has been roughly divided into five fields or regions, and these into lesser subdivisions or areas. The major subdivisions are as follows: (1) The Oil City field, lying in Oil Canyon near the north end of the district; (2) the Eastside field, embracing the territory northeast of Oil Canyon and including Anticline Ridge; (3) the Westside field, extending southeastward from Oil Canyon as far as Alcalde Canyon; (4) the Kreyenhagen field, which includes the Jacalitos and Kreyenhagen hills, Reef Ridge, and the territory southward to the Kings County–Kern County boundary; and (5) the region of the Kettleman Hills, extending from the Guijarral Hills southward to the gap separating the Kettleman from the Lost Hills.

CONTOUR MAP.

EXPLANATION.

The contour map of the Coalinga field (Pl. II) shows the structure, boundaries of the more important geologic formations, and certain culture, such as towns, section lines, and a few roads. The structure in the productive territory is indicated by contours showing the distance above (marked by a plus) or below (marked by a minus) sea level of the base of the "Big Blue" or top of zone B in the Eastside field and of the top of zone B in the Westside field. The contour interval is 100 feet. By means of this map the direction and amount of dip of the strata in the oil-bearing formation may be calculated for any point in the field, and the depth to the various productive sands or zones may be approximated for most parts of the territory.

USE OF THE MAP.

Suppose it is desired to find the probable depth below the surface of the first productive sand at the middle of the north line of SE. ¼ sec. 24, T. 20 S., R. 14 E. An examination of the map will show that this point lies approximately on the underground contour line marked "—500;" that is, the top of zone B is here about 500 feet below sea level. A close approximation of the elevation of the point may be had by looking up the elevation for the nearest derrick (see list, p. 128), which happens to be Claremont No. 4, elevation 792 feet, and calculating the difference in elevation, say 22 feet lower, either by the eye or with an aneroid barometer. The distance from the surface to the top of the oil zone mentioned would, therefore, be 500 feet plus the 770 feet, or approximately 1,270 feet. As zone B is the uppermost productive zone for this part of the field, the depth desired is 1,270 feet.

Again, suppose it is desired to find the depth to the main commercially productive zone at the center of sec. 5, T. 20 S., R. 15 E. Proceeding as before, it is found that the depth of the uppermost zone is about 1,460 feet below sea level and that the elevation of the point is about 950 feet above sea level, or that the top of the uppermost zone is about 2,410 feet below the surface. It will be found, however, by reading over the text referring to this part of the field that the most productive zone is zone D, which lies from 300 to 450 feet below the top of the upper productive zone (zone B) in this region. Therefore the distance to the top of the commercially productive zone will be 2,410 feet plus 300 to 450 feet, or between 2,710 and 2,860 feet.

Suppose it is desired to find the dip or pitch of the beds in the NW. ¼ sec. 23, T. 19 S., R. 15 E. An examination of the contours shows that the beds are pitching a little east of southeast (or striking a little north of northeast), and that the dip is about 850 feet for half a mile, or about 32.5 feet per hundred feet at right angles to the strike. The south and east components of this dip may be calculated by measuring in these directions instead of directly down the dip of the beds, which is always at right angles to the direction taken by the contours.

BASIS OF THE CONTOUR MAP.

The section lines and other culture are the result of instrument work by E. P. Davis, of the Geological Survey. The log of nearly every well in the field that was either finished or down any considerable distance on April 1, 1908, was used in the determination of the underground structure and the compilation of the data concerning the oil zones. All of the obtainable surface evidence of dip, strike, and occurrence of petroleum was also used in the preparation of this map. In those places where the surface and well-log evidence were at variance the latter was usually followed. In unsymmetrical features like the Coalinga anticline and Coalinga syncline the plane of the axis of the fold is not vertical, and, therefore, the anticline as indicated by the contours showing the underground position of certain zones will not lie directly under the trace of the same anticline or syncline on the surface.

DIFFICULTIES OF PREPARATION AND DEGREE OF ACCURACY.

After carefully plotting all of the logs on a uniform scale it was found that the greatest obstacle to overcome in the preparation of the contour map was the correlation of the strata from one well to another and from one part of the field to another. The difficulties of such correlations are doubtless familiar to anyone who has tried to work out the underground structure of any of the California fields. It must be said, however, that the structure in the Coalinga district is more regular and the conditions more favorable for a successful study and mapping of the underground geology than they are in any of the other California fields so far examined by the senior author, not excepting the Santa Maria field, which was studied in 1906 and of which an underground-contour map was prepared.[a] The effort has been made to delineate on the present map all of the details of structure consistent with the use of the well logs as confidential information, and to supplement these details by showing for the untested areas what seem to be most likely the conditions of underground structure. Within the untested areas the underground contours are of course only hypothetical and are shown by broken lines.

Regarding the degree of accuracy it may be stated that the exact elevations of practically all of the wells in the field were used in the preparation of the map. The well logs are assumed to be accurate to the usual degree—that is, ordinarily to the length of one "screw," or about 5 feet. The factor of error for the developed territory is therefore small, but will necessarily increase with the distance away from the drilled ground. Future development will add much to the knowledge of this field, and will show the inaccuracies of the contouring as here presented, but it is hoped that the benefits which may accrue to the operators from a knowledge of the general structure of the field will compensate in a measure for the errors in detail which are to be expected in a map based on incomplete data.

DETAILS OF THE PRODUCTIVE AREAS.

OIL CITY FIELD.

LOCATION.

The Oil City field occupies the territory of the southern part of sec. 17 and the northern part of sec. 20, T. 19 S., R. 15 E. Conditions in the territory immediately south of Oil City in the southern part of sec. 20, which has been tested but found to be poorly productive, will also be discussed with the Oil City field. The Coalinga Oil Company and the Home Oil Company are the only producers now operating in the Oil City field.

GEOLOGY AND STRUCTURE.

The Oil City field is situated within the belt of shale and interbedded or underlying sands of the Tejon (Eocene) formation, the oil being obtained from the last-mentioned beds. The proved productive

[a] Bull. U. S. Geol. Survey No. 322, Pl. X.

ground occupies the same general relation to the plunging Coalinga anticline as the productive territory farther southeast in sec. 28; it is on the more gently inclined or northeastern flank of the fold. Surface dips of 50° to 90° and even overturned dips occur throughout the area along the southwestern limb of the anticline, while a surface dip of 32° is the maximum for the northeastern limb. The well logs indicate a relatively constant dip of about 26° (42 to 44 feet per hundred feet) southeastward down the axis of the anticline and a relatively slightly steeper dip in the beds immediately north of it in the productive territory.

GEOLOGY OF THE WELLS.

The wells in the productive area all start in the brown shale of the Tejon (Eocene), and continue in brown, black, and blue shale to the bottoms except where they pass through the oil sand. From one to three sands are penetrated. The first is from 4 to 15 feet thick and yields the lightest oil, said to run as high as 40° B.; gas is also reported from the first sand in other wells, and in still others it is dry. The second and third sands comprise a zone 60 to 100 feet thick; in some of the wells this is petroliferous throughout almost its entire distance, while in others the two sands are separated, the upper usually running from 15 to 20 feet thick and the lower from 40 to 60 feet.

A section of the second and third sand in the productive area is as follows:

Section of second and third oil sands, Oil City area.

	Feet.
Hard sand	4
Soft pay sand	15
Very hard sand	6
Alternating hard and pay sands	47
	72

All of the sands are comparatively fine grained. The oil usually comes from the softer sands and the lower sand is generally the most productive, although it is entirely unproductive in some of the wells. The wells vary in depth from 300 feet to nearly 1,700 feet, and the productive zone is reached at depths varying from about 250 to 1,500 feet.

The southern part of sec. 20, T. 19 S., R. 15 E., has been rather thoroughly tested and, though most of the wells have yielded more or less oil, they were not deemed profitable enough to warrant continuous operation. The following log of a typical well in the abandoned territory shows the general character of the Tejon formation.

Log of Phoenix Oil Company's well No. 3, in SE. ¼ sec. 20, T. 19 S., R. 15 E.[a]

	Feet.
Pink shale	300
Sand with water	330
Dark-colored shale	420
Sand with sulphur water and oil	440
Dark-colored shale	500
White clay shale	520
Oil sand	535
Shale	540
White shale	560
Oil sand	575

This well is said to have yielded 50 to 60 barrels of black heavy oil (10° to 12° B.) for a short time. This low gravity is accounted for by the disturbed condition of the strata which the well penetrated, it being located directly on the anticline and just above an oil seepage in the canyon.

Well No. 2 of the Phoenix Oil Company, located about 300 feet west of No. 3, struck the sand at a less depth, but yielded less oil. No. 1 went to 1,300 feet, but being southwest of the anticline never produced. The above log and the conditions described are characteristic of most of the test wells put down in this area.

Following are descriptions of the wells that have been put down here south of Oil City:

Blue Goose Oil Company's well No. 1; E. ½ NE. ¼ sec. 20. Depth, 2,200 feet through brown and blue shale. No oil, but much water. Abandoned.

California Oil and Gas Company's well No. 1; SE. ¼ sec. 19. Formation, principally shale. Abandoned. Same company has well in SW. ¼ sec. 20, also abandoned.

Crescent Oil Company's well No. 1; SE. ¼ sec. 20. Depth, 900 feet. Little oil at 770 feet. Gravity, 11° B.

Mutual Oil Company's well No. 1; SE. ¼ sec. 20. Depth, 1,800 feet. Abandoned.

New York Oil Company's well No. 1; SW. ¼ sec. 20. Depth, 1,000 feet, all in brown shale. No oil. Abandoned. Well No. 2. Depth, 2,200 feet, in brown shale with few hard sand layers. No oil. Abandoned.

Selma Oil Company's well No. 1; SE. ¼ sec. 20. Depth, 1,742 feet. Little oil sand.

Zenith Oil Company's well No. 1; SE. ¼ sec. 20. Depth, 2,380 feet. A little oil sand at 1,735 feet yielding 10 barrels a day of amber-colored oil, 38° to 42° B. gravity. Later it was drilled deeper and struck a large quantity of salt water which rose to within 300 feet of the top of the hole. The oil sand in this well is probably the same as the uppermost sand in the productive Oil City area. The occurrence of salt water below this is suggestive of bottom or edge water for the Tejon (Eocene) lower oil sands. Well No. 2, same as Selma No. 1 (?).

PRODUCT.

The production of the wells in the Oil City area varies from the figure for the initial output of one well, said to have been 700 barrels of oil per day for a short time, to the daily run of certain others,

[a] Watts, W. L., Oil and gas yielding formations of California: Bull. Cal. State Min. Bureau, No. 19, 1900, p. 140.

which now will average not more than 4 barrels a day. In several wells the oil is said to have flowed over the top of the derrick when the oil sand was first penetrated, as a result of gas pressure, which soon subsided. All of the wells have to be pumped after a short initial period of spontaneous flow. The average daily production at present is about 20 barrels per well. The average normal rate of decrease per well for the field, disregarding the rapid decrease from the initial production, has been between 15 and 20 per cent per year since 1900. The productiveness of the wells increases down the nose of the anticline toward the southeast, especially near the axis of the flexure. This is shown by the fact that well No. 3 of the Home Oil Company (the original Blue Goose well) and No. 7 of the Coalinga Oil Company have been among the best producers in the group.

The gravity of the oil varies from 48° Baumé, oil of which gravity occurs only in small amounts, being reported to come from the uppermost sand in some of the wells (5 gallons of 48° oil from one well, it is said), to the usual run, which tests between 33° and 34° Baumé. There is apparently little variation in gravity between the wells up or down the dip or along the strike. The oil is greenish to brownish in color and shows little viscosity.

EASTSIDE FIELD.

PEERLESS-CALIFORNIA DIAMOND-T. C. AREA.

LOCATION.

This area comprises that part of the Eastside field which includes the northeastern portion of sec. 21 and the northern part of secs. 22, 23, and 24, extending to the line between Tps. 18 and 19 south at the northern end of the district. The companies operating in this area are the Coalinga Peerless, Octave California Diamond, Lorene, T. C., Wm. Graham, Imperial, Bowling Green, and California Oilfields, Ltd.

GEOLOGY OF THE WELLS.

All of the wells in this area start down either in the Santa Margarita or Jacalitos formations (upper Miocene) between the top of the "Big Blue" and the base of the Etchegoin. They all reach, and some of them entirely penetrate, the Vaqueros (lower Miocene) formation, which includes the oil-bearing zones, B, C, and D, of this part of the field. The variation in the beds penetrated is quite rapid, as is indicated by the logs, and, with the exception of the "Big Blue," it is seldom possible to trace a single stratum for more than one-eighth or one-fourth mile.

The map (Pl. II) indicates by contours the distance of the base of the "Big Blue" above or below sea level. The "Big Blue" varies in thickness in the wells—if the distance penetrated be counted as equivalent to the thickness—from about 260 feet at the western edge of the area to over 350 feet in deeper wells toward the east. In fact, one of the deep wells disclosed a continuous shale formation for about 640 feet, but it is not believed that this entire thickness is included in the "Big Blue" farther west. One of the unique characteristics of the "Big Blue" for this area, and also for nearly the whole of the rest of the Eastside field, is the red-shale layers which are found at various points interbedded with the blue variety. The red shales are well shown in outcrop in secs. 3 and 10, T. 19 S., R. 15 E., where owing to their peculiar tints they may be seen for a distance of several miles. The red shale consists almost entirely of comminuted serpentine, which is naturally green but is turned red by the oxidation of the iron, of which serpentine contains a relatively high per cent. The red shale appears prominently on the sumps, where it forms brilliant coatings as the material is dumped from the bailers.

Water sands from 20 to 175 feet thick are found just above the "Big Blue" from the western part of the NW. $\frac{1}{4}$ sec. 22 eastward to the deepest wells. Lenses of water sand are also reported in the "Big Blue" from the middle of sec. 14 eastward.

Seashells are another characteristic of the logs of this part of the area. They occur from about 120 feet above the "Big Blue" in the Peerless area to 230 feet above it in the wells in sec. 12. Some of the deeper wells also show a layer of seashells about 530 feet above the "Big Blue."

A more or less persistent zone of sulphur sands occurs from 20 to 180 feet above the first productive zone, zone B, but is not reported in all the wells. Sulphur water also occurs below the productive sands in two of the wells only, while certain of the Peerless wells are said to yield no water whatever. These facts clearly indicate that the water occurs in more or less isolated lenses of sand, similar, in a general way, to the lenses carrying the oil.

Between the base of the "Big Blue" and the first productive oil sand (zone C) there is about 350 feet of dry sand, shells, and, just above the oil sand, some blue or brown clay or shale layers. These last are often interbedded with dry or poorly saturated oil sands (zone B, in part). The thickness of the strata intervening between the "Big Blue" and the top of zone C reaches 450 feet in the deeper wells farther east down the dip.

Very little regularity exists in the oil zones, as is shown by the well logs. The productive beds (zones C and D) consist of alternating coarse sands, fine gravels, blue and brown shale and shells, with coarse gravel at the base of zone D. The productive measures are usually about 225 feet thick, measuring from the top of the first productive sand to the brown Eocene shale of the Tejon formation, and though they comprise both zones C and D, a separation of the two is not possible in many of the wells. The total thickness in the wells from the base of the "Big Blue" to the brown shale of the Tejon is a little over 600 feet.

Various names have been applied to certain individual sands that have been traced for short distances throughout this area. Among these is the "Sauer Dough" sand, which is the uppermost sand in some of the wells along the western edge of sec. 22. It is usually about 10 feet thick. About 40 feet below the "Sauer Dough" is a 40-foot sand known as the "Pulaski." A careful comparison of the logs in the area shows that these two sands, and others also to which local names have been given, are not traceable for any great distance, although the names have been applied to various strata in wells over other parts of the Eastside field.

PRODUCT.

Nearly all of the wells in this area have been drilled since 1904, so that data concerning decrease in production are rather meager. The production of the wells varies from about 25 to something like 700 barrels, the production increasing down the dip, other things being equal. The T. C. well in sec. 22 is said to yield about 400 barrels a day, which is believed to be a fair initial average of what would be encountered over most of the area in properly handled wells 1,500 feet or more in depth. The average production for the wells in the area is about 125 barrels a day. The yield depends largely on the handling of the well, for holes going down under practically the same conditions give quite different results under various managements. One well which had an initial production of 200 barrels now yields only 20 to 25 barrels a day. This decrease is probably due not entirely to natural causes but to a sanding up of the hole. The gravity of the product from this area varies from 18° to 24° B. So many sands are perforated that it is usually impossible to tell the gravity of oil from any particular one. However, the uppermost important productive zone (top of zone C) in the area is believed to yield oil between 20° and 21° B. gravity. The next sand, say about 80 feet below the first, yields 24° B. gravity, or possibly slightly better, while the lowest sand (base of zone D), which rests directly on the shales of the Tejon, produces oil of 18° or 20° B. gravity.

Some of the wells yield a little water with the oil, and it is claimed by some drillers that this water comes from the oil sands, but it is the belief of the writers that in nearly every instance the water has leaked in from the surrounding water sands and is not obtained directly from the oil sands. Relatively little sand is yielded by the wells after the initial period of production, but much trouble has been encountered in some of the deeper wells owing to the gas pressure forcing the sand in from the bottom. Gas accompanies the oil in all of the wells and is also encountered alone in isolated pockets, many of which are above the productive zones. Other conditions being the same the greater gas pressure occurs in the deeper wells.

TECHNOLOGY.

The best success in shutting off the water in this area has been in landing the casing in a blue shale just below the sulphur-sand zone. Surface waters are shut off above this with a larger casing, but the purity of the oil depends entirely upon the careful handling of the lower waters immediately overlying the oil sands.

STANDARD-CARIBOU-CALIFORNIA MONARCH AREA.

LOCATION.

This area covers the northeastern portion of sec. 27, the southern part of secs. 22, 23, and 24, all of secs. 25 and 26, and the northern part of secs. 35 and 36. The following companies operate in this area: California Oilfields (Ltd.), the Standard, Caribou, Associated, Twenty-Two, Record, Pittsburg, and Boston & California.

GEOLOGY OF THE WELLS.

The wells in this area, as in the area farther north, start down in the Santa Margarita and Jacalitos (upper Miocene) sands and shales between the top of the "Big Blue" and the basal Etchegoin. In the area where secs. 21, 22, 27, and 28 meet, the "Big Blue" is about 220 feet thick in the wells, increasing toward the eastern limit of the productive territory to about 320 feet. Red shales are reported interbedded in the "Big Blue" in nearly all of the wells throughout the area, apparently thickening and becoming relatively more prominent in the deeper wells toward the east and north. Some white and light-blue shale layers also occur in the same zone, and in the western part of the area gray and brown dry sands are encountered above it. From a point a short distance west of the middle of the line separating secs. 22 and 27 the same sands contain water at various distances above the shale.

All of the strata from the base of the "Big Blue" to the top of the Tejon (Eocene), embracing a distance in the wells of from 620 feet to over 800 feet, are more or less petroliferous throughout this area. Three oil zones may be defined within these limits. The first zone (zone B, the top of which is shown on Pl. II) begins immediately at the base of the "Big Blue" and is from 100 to 180 feet thick, the greater thickness occurring in the deeper wells. In the western part of the area zone B consists of dry sands, dry oil sands, or poorly saturated oil or tar sands; farther east it is commercially productive in some of the deeper wells but not in all. Where productive, as in the western part of sec. 26, the gravity of the oil in zone B is about 14° to 16°. Below zone B and between it and zone C the strata are largely shale and dry sand.

The second and third zones (zones C and D) are closely related, the second being the uppermost important producer over most of the area. Zone C consists of medium-grained sand yielding light-gravity oil (24° B., or better), is about 100 feet thick, and begins about 400 to 480 feet below the base of the "Big Blue" There are usually from 1 to 4 productive sands in this zone. The lowest productive zone (zone D) rests directly on the shales of the Tejon (Eocene), is very coarse, consisting of pebbly sand or fine gravel, and is usually the best producer as regards quantity, although the oil is of but 20° to 23° B. gravity.

Sulphur water overlies zone B in the area north of a line drawn south of Caribou Nos. 11 and 10. Fossil shells are reported at the base of the "Big Blue" in some of the wells, while in others, as in the region farther north, they occur about 450 feet above the base of the "Big Blue." The sea shells in some of the Caribou wells are found just above the oil sand and associated with it.

PRODUCT.

Most of the wells in this area also have been begun since 1904, so that figures for decrease in production are meager. All of the productive sands in many of the wells are perforated so that it is often impossible to tell the production or gravity of any one sand. However, the general features of variation are known and will be indicated. The variation in the initial production in the wells is from about 150 to 1,600 barrels a day, and the average production at present is about 400 barrels. The best producers, as a rule, are among the deeper wells, although for one which is well up on the dip (SE. ¼ sec. 21) an initial yield of 1,500 to 1,600 barrels a day is reported. This well obtained 200 barrels a day from the upper sands, but was lowered into the deeper sands, where it made its phenomenal record. Besides the one mentioned there are at least two other wells in the area that have produced more than 1,000 barrels a day. The average decrease in production for three years has varied from about 20 to 40 per cent, but some wells are said to have held out much better than this.

The gravity of the oil in this area varies from 16° to about 24° Baumé. The heavy oil comes from the upper sands (zone B), which are usually more productive in the deeper wells. A well in the W. ½ sec. 26 is said to have yielded 600 barrels of 15° or 16° oil from zone B when first drilled. The middle zone (zone C) produces oil of about

24°, while the lower, coarser, but generally more productive sands (zone D) yield oil of 21° to 22° B.

Gas occurs in practically all of the wells. In some of them there is sulphur, but most of them yield a good quality free from this element. The influence of one well on the pressure in another is often very marked. A certain well, for instance, dropped off more than 25 per cent in production when another well within 300 feet of it was brought in.

STANDARD-CALIFORNIA OILFIELDS (SEC. 27) AREA.

LOCATION.

This area includes the eastern part of sec. 28 and the western part of sec. 27 excluding the portion along the southern line of sec. 27. The Standard and the California Oilfields, Ltd., are the only companies operating in this area.

GEOLOGY OF THE WELLS.

All of the wells start down in the Santa Margarita (upper middle Miocene) and Jacalitos (upper Miocene) formations (above the top of the "Big Blue" and below the base of the Etchegoin), which usually include alternating sands and shales with occasional water sands. These water sands as a general rule are in the form of lenses and can seldom be traced in the wells for more than an eighth cf a mile.

The "Big Blue" maintains a pretty uniform thickness of about 250 to 300 feet throughout practically the whole of this territory. In the wells along the middle of the line between secs. 27 and 28, there is a fairly persistent stratum of water sand immediately overlying the "Big Blue." There are other water sands above this lowest one in some of the wells, but none that can be traced far. An interesting stratum encountered in the wells beginning in the vicinity of the California Oilfields, sec. 27, No. 20, and extending down into the northern part of sec. 34, is known as the "St. Paul sand." It lies about 830 feet above the base of the "Big Blue," or from about 150 to 600 feet below the surface. It is about 30 feet thick and is hard, but is believed by some of the operators to be capable of yielding commercial quantities of oil, though, so far as known, it has never been thoroughly tested. This occurrence is rather puzzling, as there are no other oil sands within several hundred feet of it, and the origin of its petroleum is difficult to explain.

The oil-bearing formation in the area under discussion extends from the base of the "Big Blue" for about 655 feet, as measured in the wells, down to the top of the brown shale of the Tejon (Eocene). This distance between the base of the "Big Blue" and the brown shale is apparently regular over that part of the area which has been tested.

The wells in the deep territory have not penetrated the entire thickness of the oil sands, so that the exact thickness of the sands is not known for wells far down on the dip.

Three zones are recognizable in this series of productive beds. The first (zone B) occurs at the base of the "Big Blue," is about 15 to 20 feet thick, and yields from 30 to 50 barrels of 21° oil in the shallower wells.

The second (zone C) is about 300 feet below the top of the "Big Blue," has a thickness of 60 feet, and produces daily from 100 to over 1,000 barrels of 22° to 24° oil per well. A group of wells in the middle of the western part of sec. 27 and in the eastern part of sec. 28 produce oil of from 25° to 31° B., the initial production of the wells varying from 125 to 1,900 barrels per day. The oil from zone C, in this local area of unusually light oil, is kept separate in most of the wells, but whether or not all of the yield from the big producers in this light-oil area comes from zone C is not known. The sands in this light-oil zone are finer grained than those in the zone above or the zone below.

The third oil zone (zone D) consists of coarse, pebbly sands and fine gravels, and extends practically from the top of the brown shale of the Tejon upward for over 100 feet. Oil-bearing sands are found at practically all horizons in one well or another from the base of zone C to the top of zone D, so that a separation of the two is necessarily more or less arbitrary.

PRODUCT.

The wells in this area have all been drilled since 1902. The product of those wells deriving their supply from the upper sands (zone B) varies from 30 to 50 barrels a day of 21° B. oil. The middle zone (zone C) yields from 125 to 1,900 barrels per well a day, the gravity ranging from 24° to 31° B. One well which had an initial production of 1,900 barrels a day in 1904 dropped to 1,300 barrels a day after one and one-half years. Several of the wells yield on an average 300 to 400 barrels a day, while another group averages but 125 barrels of 26° B. oil. The third zone (zone D) yields oil of 22° to 23° B. It is the best producer, as far as quantity goes, in this part of the field. The better gravity and greater production in this particular area is believed to be due to the position of the wells adjacent to the axis of the anticline, where the Eocene shales (Tejon), from which the oil is derived, are much more fractured, and where, in consequence of this fracturing, the oil is permitted to migrate more easily and with less loss in quality into the overlying porous sands. The concentration of the oil within the Tejon, previous to its emigration, was also doubtless accentuated along the anticline by the action of the water which occurs associated with or immediately underlying the oil sands in the Tejon.

The presence of the light oil in the finer sediments is believed to be due to the fact that the lighter hydrocarbons can escape more easily from coarser reservoirs than from fine-grained ones, so that, when once charged with the oil, the finer-grained sands allow it to maintain its original quality more perfectly than a coarse sand would. As would be expected, the production under the same pressure is considerably less in finer sediments than it is in coarse sands, but the length of productivity is consequently greater in the former than in the latter.

CALIFORNIA OILFIELDS (SEC. 34)-COALINGA-MOHAWK AREA.

LOCATION.

This area comprises the whole of secs. 34 and 35, T. 19 S., R. 15 E., and secs. 1, 2, 3, 4, 11, and 12, T. 20 S., R. 15 E. The California Oilfields, Ltd., the Southern Pacific, W. K., Turner, Claremont, and Coalinga-Mohawk are the companies operating in this territory.

GEOLOGY OF THE WELLS.

As in the other areas described, the base of the "Big Blue" is the horizon shown by the contours on the map (Pl. II). The wells in the northern part of the area start down in the Jacalitos (upper Miocene) beds immediately underlying the base of the Etchegoin. Those south of the line marking the base of the Etchegoin start in the sands or clays of that formation. The "Big Blue" in the wells of this area varies from 250 feet in thickness in the northwestern portion to about 380 feet at the southwestern border. The peculiar red, green, and light-blue facies of the shale that are characteristic of the "Big Blue" in the deeper wells farther north are also found in the deep wells in portions of this area. In the northwestern portion water sands appear to be interbedded at the base of the "Big Blue," as are also some tar and dry oil sands, with occasional gas pockets. There are also other water sands in the deeper wells, an especially persistent zone occupying a position about 600 to 800 feet above the base of the "Big Blue" in the wells in the southern part of the area. Some of the water in this zone is said to contain appreciable amounts of sulphur.

The "St. Paul sand," described in the last area, also occurs in the northern part of this territory, where it is encountered in practically all of the wells, in none of which, so far as the writers are aware, has it ever been tested. Those wells which have been put down to the brown shale of the Tejon (Eocene) indicate that the formation between the base of the "Big Blue" and this shale has practically the same thickness of 650 feet or thereabouts that it has in the region to the north. The whole of this distance is occupied by alternating sandstones and shales, which are more or less productive in t' › various wells. The relations existing between the various oil sands in this area are not well known, but it is believed that the sequence of zones, including B, C, and D, is similar to that in the area last described. A 10-foot oil sand carrying 17° B. oil occurs at the base of the "Big Blue," probably corresponding to the one which yields a 16° B. or heavier oil in sec. 26, and which has been correlated with zone B. One hundred feet below the "Big Blue" the second sand, possibly zone C, is penetrated, this being productive through about 20 to 25 feet. About 400 feet still farther down is the third zone (zone D), which is believed to rest upon the Eocene shale (Tejon). A thin layer of sulphur water is reported in some of the wells just above this third zone, but enough blue or brown shale intervenes to allow complete shutting off of the water before reaching the productive zone.

PRODUCT.

The wells in this area are only two or three years old, but since their inception they have maintained a reputation as the biggest producers in the field. The oil in these wells is usually accompanied by large quantities of gas under strong pressure. As an instance of their unusual productiveness, it is said that one well in the northern part of sec. 34 yielded about 7,000 barrels of oil in eighteen hours. In ejecting this large amount of fluid from the hole the casing was practically all torn out. This well is now producing but 150 barrels a day, which indicates that the great production was due to the extremely high gas pressure. Another well near the center of the southern part of sec. 27 is said to have yielded 4,500 barrels of oil a day for some little time. This well is now believed to yield about 3,000 barrels a day. The gravity of the oil from these big producers is between 23° and 24° B.

Another well in the northern part of sec. 34 yielded on an average about 1,000 barrels a day for over ten months. Still others of these wells ran from 600 to 800 barrels a day. One well, which yielded 26° B. oil as long as it flowed, now yields a mixture of 23° B. oil when it is pumped. This implies that the lighter oil is probably under the greater gas pressure, and when this pressure is removed, the heavy oil either forces back the lighter fluid or allows only a small percentage of it to enter the well. The lower zones (zones C and D) in one well are said to yield a stratum of 29° B. oil at the top, 22° B. in the middle, and 26° at the base, with an average of about 28°.

STANDARD-STOCKHOLDERS-HANFORD AREA.

LOCATION.

This area comprises all of sec. 28, except the extreme eastern edge, which is described in a previous section (p. 84). The Standard, Hanford, and Stockholders oil companies are the only operators.

GEOLOGY OF THE WELLS.

The "Big Blue" in this territory varies from about 200 to 230 feet thick in the wells. A layer of water sand is found just above it in the eastern part of the area, and in one or two instances lenses of water sand have been reported as occurring in the "Big Blue" itself. The oil strata extend intermittently from the base of the "Big Blue" for about 655 feet to the brown shale of the Tejon (Eocene). The first 400 feet of the productive measures consists of alternating gas sands, oil sands, dry sands, and tar sands interbedded with shales and clays, and has been correlated with zone B, although it is believed to comprise not only the zone B of the areas toward the east, but the strata to the top of zone C. In the northwestern part of the area this upper zone is more or less productive, some of the wells which produced from it alone yielding from 10 to 30 barrels per day of 20° B. oil.

One or two persistent layers of water sand occur from 50 to 100 feet above the base of zone B, or above the top of the second or light-oil zone (zone C). Enough blue or brown shale intervenes between this water sand and the productive beds below to permit shutting it off. Big oyster shells are reported in some of the wells just above the second zone, these probably coming from the same layer as that yielding the oysters in the Vaqueros formation on Laval grade. Zone C consists largely of fine sand from 20 to 60 feet thick and yields oil of about 21° to 22° B. gravity. The third zone, or zone B, consists of coarse sand to gravel and begins about 100 feet above the brown shale of the Tejon (Eocene). It is productive throughout its entire depth, and yields more than any other of the zones in this group of wells. The daily production varies from 40 to 300 barrels per well of 18° to 22° B. oil.

Toward the axis of the anticline which bounds the present developed territory on the southwest the strata are more or less irregular, on account of the steep dips which are developed by this profound fold. The logs of the wells along the axis are quite irregular and indicate variable conditions in both the dip and the productiveness of the beds. Water is also more troublesome in these wells, owing, it is believed, to the disturbed conditions of the elsewhere impervious beds that surround the water sands. There is very little gas in the sands toward the western edge of this area.

PRODUCT.

The wells in the area under discussion are the oldest in the Coalinga district except those in the Oil City area, and many of them have produced continuously since their inception. The first zone (zone B) yields up to 30 barrels per day of 20° to 22° B. oil; the second (zone C) yields a somewhat lighter oil, from 21° to possibly 23° B. and the third (zone D) produces as high as 300 barrels of 18° to 22° oil. Some of the wells yield sand from the lower productive beds and water is also mixed with the oil in some of the wells in the broken formation near the axis of the anticline. In none of the wells in this area is the water believed to come from the bottom of the oil zone.

WESTSIDE FIELD.

CALL-CONFIDENCE AREA.

LOCATION.

This area is located in the southwest corner of T. 19 S., R. 15 E., and comprises the territory controlled by the following companies: The California Oilfields, Ltd., the Call, Keystone, Ajax, American Petroleum, Ætna Petroleum, Commercial Petroleum, California Diamond, Main State (formerly the Guthrey), California Monarch, Confidence, and Kern Trading and Oil. The wells are located on the southeastward-dipping monocline of the Westside field at a point where the strike of the beds begins to bend from northeastward to eastward around the axis of the Coalinga syncline.

GEOLOGY OF THE WELLS.

All of the wells start down in the soft shales, sandstones, or gravels of the basal Etchegoin or in the upper Miocene beds immediately underlying this. Toward the western part of the area the wells apparently penetrate only through the upper Miocene formations. On the western side, that is, in the deeper wells of the Call, California Oilfields, Ltd., and Commercial Petroleum, the wells apparently reach sands in the lower Miocene (zone D) that are lacking or have not been reached in the wells in the western part of the area.

Zone B, the depth of which below the surface is indicated by contours on the map (Pl. II, in pocket), will first be described. Toward the western part of the area it contains the productive sands and is found from about 650 to 1,050 feet below the surface. The oil in this zone is apparently under considerable gas pressure, for in nearly all of the wells, even the shallower ones, the oil rises a considerable distance in the casing when the sand is first penetrated. The sand in the shallower wells varies from 10 to 20 feet in thickness, thickening toward the northeast from the region of the Kern Trading and Oil territory. The sand is medium grained to coarse and soft, and the wells producing from it yield large quantities of sand with the oil, especially at first. Some of the shallower wells have been known to flow when first brought in. Farther east, in the vicinity of the eastern Confidence wells and those of the Main State or Guthrey leases, the zone is apparently irregular and some of the logs of the wells, although reporting a production from the horizon at which the sands are found farther up on the dip, do not mention the thickness of the sands within the zone. Guthrey No. 1, which was the biggest gusher of this part of the field, might be mentioned as an illustration of the irregularity. The behavior of this well was quite unusual and the exact location of the sand producing the gas and oil which flowed so strongly at first is doubtful. Enough sand was ejected from this well to cover the derrick floor and the surrounding ground over 6 feet deep.

In the deeper wells zone B is apparently represented by two sands which are separated in some instances by a waxy clay. The total thickness of the sand in these wells runs as high as 50 feet. Still farther down the dip, or in the deepest wells in the area, zone B apparently becomes unproductive, although it yields evidences of gas and petroleum in small quantities. In one of the wells this zone was pumped for three weeks, but the operators concluded that there was water in it and abandoned their efforts.

About 200 to 300 feet above zone B is a zone of tar sands (zone A), which, as the name implies, are either dry or yield oil of heavy gravity. These sands vary in number and thickness from well to well, although the zone as a whole is fairly persistent over the entire area. Sulphur water occurs within zone A, usually at the base of the first tar sand, and at some of the wells it is found at two horizons within the zone. The thickness of the tar sand varies from a minimum of 10 feet in some of the moderately deep wells to nearly 100 feet or possibly more in those farthest up on the dip. Thicknesses approaching 100 feet are also occasionally met with in the deep-well area.

About 200 feet above the zone of the tar sands (zone A) is a very persistent stratum of water. This water is mineralized in all of the wells and in some shows traces of sulphur. Above this water zone are usually one or two other water sands, the first being only about 5 to 10 feet thick, but yielding considerable water. The second is of less importance and is apparently lacking in many of the wells.

In the deeper wells toward the eastern part of the area the most productive sands apparently lie below zone B and are believed to be in part the equivalents of the lower Miocene sands (zones C and D) which are the productive sands of the Eastside field. The exact relations of these zone D sands to the overlying ones are perplexing, but it is believed that zone D does not extend westward past the middle of the area under discussion, although to the knowledge of the writers no well has yet been put down which passes entirely through the strata overlying the Tejon (Eocene) in this part of the field. Some of the wells have reached what they call the black or brown shale, but it seems likely that these brown shales may be simply petroliferous shales intercalated in the sands of the Vaqueros (lower Miocene). This lower Miocene sand zone (zone D) lies from 100 to 300 feet below zone B. Productive lenses are found at two or three points throughout the zone, but no continuous oil sands have been definitely traced between the wells.

Taking the logs as a whole, they present the following features in passing downward from the surface. First, the incoherent soil and gravel, then a thick series of dry gravels, sands, and shale or clay, with occasional hard sandstone shells. The first water is encountered usually between 240 and 500 feet. From this downward two and sometimes three other waters are penetrated before reaching the tar sand zone (zone A). The zone of the lower water sand or sands is often marked by numerous hard sand shells. After passing through zone A, which varies from a few feet to over 300 feet in thickness, a 200-foot zone of blue shale is encountered. Below this occurs zone B which is characterized by medium-grained to pebbly sands, brown shales, and several well-defined shells. The shallower wells usually stop at the base of this zone, but the deeper ones penetrate some shale and sands from the bottom of zone B to the top of the third zone, which includes zones C and D and is usually characterized by hard shells and medium-grained sands.

PRODUCT.

The production of the wells in this area varies from an initial output of 20 to 50 barrels in the shallower wells to 3,000 or 4,000 barrels in some of the deeper ones, such as Guthrey No. 1, which was a pronounced gusher when first brought in. The daily average for these wells runs somewhere between 100 and 200 barrels, but some of them average as high as 300 to 350 barrels over long periods.

The gravity of the oil runs from 14° to nearly 20° B., the average for the shallower wells being about 16°, and for the deeper wells something like 18°. The best oil apparently comes from the middle zone (zone B), which is believed to correspond in a general way with the light-oil sands farther south in the Westside field.

MERCANTILE CRUDE-S. W. & B. AREA.

LOCATION.

This area comprises the southern part of the Kern Trading and Oil, Confidence, California Monarch, and E. W. Risley leases on sec. 31, T. 19 S., R. 15 E., the Fresno-San Francisco and the northern parts of the Cypress and Pennsylvania-Coalinga properties in the northeastern part of sec. 1, T. 20 S., R. 14 E., and the Mercantile Crude, York-Coalinga, S. W. & B., New San Francisco Crude, and the northern half of Esperanza in sec. 6, T. 20 S., R. 15 E. The wells are located on the southeast-sloping monocline which dominates the structure of the whole Westside field.

GEOLOGY OF THE WELLS.

The wells in this area all start down in the basal Etchegoin (upper Miocene) clays, sands, gravels, etc., and the Jacalitos (upper Miocene) beds immediately underlying these. Three more or less well-defined petroliferous zones are developed in this area. The top of the principal productive zone (zone B) is shown by contours on the map (Pl. II). In wells high up on the dip the sand in zone B is coarse, and it usually contains pebbles the size of the thumb or sometimes even larger. Both immediately above and below the most productive part of the zone are sands in which the oil is of heavier gravity than that in the most productive part. The reason for this variation in gravity between sands so close together is not at present known, but the variation may be due, in part at least, to variation in grain of the sands. Farther down the dip the sand becomes somewhat thicker, but is still quite coarse and in some of the wells is characterized by the presence of shark's teeth. The coarseness of the sand and the gas pressure are conducive to good productions, and it is not unusual for wells at first to obtain as high as 300 or 400 barrels a day from this one sand. In the deeper wells the zone apparently contains but one sand, which is in most cases underlain by a more or less persistent hard sandstone shell. The gravity of the oil in zone B runs about 17° B. and is apparently constant throughout the area. From 50 to 100 feet above zone B is a 100 to 200 foot zone (zone A) of tar sands similar to those encountered in the wells toward the north. This tar zone is thickest in the northwestern part of the area, where it consists of from one to three dry oil sands or tar sands, which sometimes contain heavy oil and occasionally water associated with the oil. Eastward, or down the dip, the tar sand decreases rapidly in thickness, until in the deepest wells in the area the tar zone is represented by but one or two sands which never attain more than 10 or 20 feet in thickness. Immediately overlying zone A is a persistent stratum of sulphur water, which is encountered in practically all of the wells in this area and is known in general under the name "big sulphur" or "main sulphur." Beneath this sulphur water in most of the wells is a hard sand shell, which is apparently more or less persistent throughout the area. Still another sulphur water is encountered a little above the lower one in some of the wells, but does not appear to be as persistent as the "main sulphur."

Below zone B in the deeper wells is still a third petroliferous zone (zone D), which may correspond in part to the lowest zone in the area immediately north. It is penetrated by but two or three wells and its productiveness is more or less uncertain. In one log this lower sand is mentioned as brown shale, although the same log shows that the casing was perforated at this point, thus indicating that the formation was oil bearing.

The water sands in the area are usually three or four in number, the uppermost being encountered at from 145 to about 375 feet in depth. The first sand is apparently not so productive as the second, which yields plenty of water in many of the wells. Below the second sand is a third and sometimes even a fourth, before the sulphur sand, immediately overlying the tar zone, is encountered.

Typical well log in Mercantile Crude-S. W. & B. area.

	Feet.
Surface soil and incoherent sand and gravel, followed by harder shales, sandstone, and gravels	200
First water sand	5- 20
Shale	50+
Second water sand.	
Shale, sometimes containing one or more water sands	300
Gravel, more or less persistent stratum, apparently carrying water in several of the wells, especially those nearest the outcrop.	
Shale	100
"Main sulphur" water	5- 20
Tar sand (zone A)	100-200
Shale	50-100
Productive sands (zone B)	20- 50
Shale, largely brown	50-200
Zone D	20- 50

The depths of the wells in this area vary from about 1,000 feet to over 1,700 feet.

PRODUCT.

The production varies from 12 barrels in the wells farthest west to about 400 barrels in the deeper and more productive ones. Large quantities of sand usually accompany the oil, especially in those wells high up on the dip, and even in some of those which penetrate the sand at much greater depth. The gravity of the oil varies from about 13° to 17½° B., the average for the area probably being about 16°.

ZIER-PORTER AND SCRIBNER-M. K. & T. AREA.

LOCATION.

This area comprises the southern part of sec. 1, T. 20 S., R. 14 E., the southern part of the Esperanza property, sec. 6, T. 20 S., R. 15 E., and the regions in sec. 12, T. 20 S., R. 14 E., and secs. 7 and 8, T. 20 S., R. 15 E. The companies operating in this area are the Zier, Ward, Seneca, Cypress, Pennsylvania-Coalinga, Esperanza, Shawmut, Section Seven, Coalinga Pacific, Porter and Scribner, Brix and Buntin (B. & B.), California and New York, and M. K. & T. The wells are located on the flanks of the southeast-dipping monocline which governs the structure in the Westside field.

GEOLOGY OF THE WELLS.

The wells start down in the basal Etchegoin or the immediately underlying soft beds of the Jacalitos formation. Zone B, the one shown in contour on the map (Pl. II), is at present the most important zone in this part of the field, and yields the greater part of the production. In the western part of the area it varies from alternating sands and shales to a single bed of coarse sand 25 feet thick. The gravity of the oil from the zone in this part of the area varies from 13° to 14° B. Farther east and lower down on the dip the gravity of the product from zone B is considerably higher, ranging from 17° to 18° B. The beds yielding this lighter oil may possibly not be continuous with those farther west which produce the oil of 14° B. gravity. On the contrary, the sands yielding the latter may possibly be represented in the eastern part of the area by the sands yielding 14° B. oil which immediately underlie the 17° B. oil sand. The 17° B. oil sand is not fine grained, but is fairly coarse and in many of the wells contains shark's teeth, as it does in the area farther north. The zone, as indicated by logs, varies in thickness from 7 to 60 feet in the central part of the area. The production from a single sand in this zone ranges from 40 or 50 barrels up to the daily maximum of about 200 barrels per well. The light-oil sand appears to be missing in some of the wells according to their logs, but it is believed that the formation is represented in the well, but was overlooked by the driller while the hole was full of water. In the deeper wells, toward the eastern end of the area, zone B maintains the characteristics just described, varying in thickness from 8 to 30 feet, apparently being mixed with some shale in the thicker portion.

As in the areas farther north, zone B thickens rapidly toward the east until in the region of sec. 8, T. 20 S., R. 15 E., indications of petroleum are found throughout a vertical distance of over 1,100 feet. Here zone B is believed to be represented by what is known as the third or light-oil sand of the M. K. & T. wells, which lies several hundred feet above the most productive sands in those holes, is medium grained, nearly 100 feet thick, and is said to yield oil of 22° B. If zone B is continuous, wells located between the Porter and Scribner and M. K. & T. leases ought to show a gradation in gravity from 17° to 18° B. in the former to the 22° B. oil in the latter, which is much farther down the dip. This decrease in specific gravity (increase in degrees Baumé) down the dip agrees with the mode of variation found in most instances in the other California fields examined by the writers.

The same tar-sand zone (zone A) is encountered above zone B in this area as is found in the same portion throughout most of the remainder of the Westside field. It varies in thickness from 20 or 30 feet to over 100 feet, being exceedingly irregular as reported in the well logs, although it is on the whole believed to be thicker down the dip toward the east. The tar sands are usually intercalated with shale and are often dry, but in some wells yield a small production of heavy oil of about 14° B. gravity or heavier. Prominent sandstone shells are usually associated with the sands and shales of this zone, some of these shells being traceable from well to well, and one in particular, of considerable importance, has been called the "Big Shell."

Below zone B and closely associated with it is a zone of 14° or 15° B. oil. This zone (zone D) has been penetrated in some of the wells for over 300 feet and found to consist of alternating sands and blue and brown shales, the brown shales usually predominating. It is barely possible that this lowest shale in the deepest wells is Tejon (Eocene), but no proof of this is available. Zone D is probably equivalent in part to the lower Miocene sand of the Lucile well and the wells in the Eastside field. In the deepest wells, which obtain most of their oil from zone D, the latter is always more productive than zone B.

Three or more water sands are usually encountered in the wells in this area. In the shallower wells and even in some of the deeper ones the water sand is met at depths of less than 200 feet. Below this first layer and separated from it by about 400 feet of shale is usually the second sand, but in some of the wells within this distance minor beds carrying water are encountered. Below the second main water sand and immediately overlying the tar zone (zone A) is a rather persistent stratum of sulphur water reported in most but not all of the wells. It is more commonly found in the deeper holes and may be represented in the wells toward the western part of the area and higher up on the dip by certain members of the tar-sand zone. If this be so, it is interesting as showing that the hydrocarbons in the tar sand have been forced upward by the sulphur water which fills up this particular porous stratum, presumably under hydrostatic pressure.

Typical well log in Zier-Porter and Scribner-M. K. & T. areas.

	Feet.
Surface clay and sand with a little gravel	200
Water sand	20- 40
Blue shale	350
Water sand or water gravel	40
Sulphur water sand (main sulphur)	30- 50
Blue shale or shells	10- 20
Alternating tar sands (zone A) and shale with 50 or more feet of shale and shell at the bottom	200
Productive 17° or 18° B. oil sand (zone B)	10- 60
Alternating oil sands and blue and brown shales, including zone D	300

PRODUCT.

The production of the individual wells in this area varies from 40 or 50 barrels to a maximum of about 300 barrels per day. The gravity of the oil in those wells in the western part of the area, well up on the dip, is about 12° to 14° B., while in the deeper wells, producing from the light-oil sand, an average of about 17° or 18° B. oil is obtained. The deepest well in the area, the M. K. & T., is said to yield oil of about 16½° B. This oil is believed to come from zone D, in the Vaqueros (lower Miocene) formation.

ASSOCIATED-CALEDONIAN-UNION AREA.

LOCATION.

The area described under this heading embraces the region from the Union lease in sec. 13, T. 20 S., R. 14 E., southward to the southern part of sec. 36 in the same township and range. It includes well No. 5 and all other Associated wells farther north in sec. 36; also the properties of the Kern Trading and Oil, Southern Pacific Railroad, Valley Slope, Cawder, Blue Diamond, Caledonian, Angelus, Ozark, Euclid, Marengo, Traders, Norse, Premier, Claremont, Wabash, Inca, St. Paul-Fresno, Coalinga Western, New Home, M. M. Kew, Sleep & Fitzgerald, Coalinga Banner, Coalinga Petroleum, Elgar Adams, and Union oil companies.

STRUCTURE.

The wells in this area are located on the east-dipping monocline of the Westside field, the southern part of the area being located near the point where the strike of the beds changes from south to east of south. Except for a local flexure, which is possibly the continuation of one of the lines of disturbance in the White Creek syncline, the general position of the beds is regular and they have an easterly dip of 11° to 22°. The beds apparently flatten out in passing east from the steeper hills in the western and southwestern parts of the area to the valley floor.

GEOLOGY OF THE WELLS.

The wells start down in the soft beds of the Etchegoin formation or of the immediately underlying Jacalitos formation. Zone B, shown in contour on the map (Pl. II), is the principal productive zone in this field, as in those farther north. In the northern part of the area the zone consists usually of a single medium to coarse grained sand, varying in thickness from 20 to 30 feet. This thickness is fairly uniform throughout the northern part of the area, except that portion well down on the dip, where the zone apparently thickens and is penetrated for nearly 40 feet in some of the wells. It also thickens locally toward the western edge of the area, 50 feet of productive sand being recorded in one of the shallower wells. It is believed, however, that in this well a part of the thickness is made up of intercalated shale.

Southward the sand apparently becomes less and less productive, the southernmost well so far drilled which is believed to obtain oil in commercial quantities from this zone being Associated No. 5. Here the productive sand is practically of the same thickness as the average farther north, but in the wells still farther south the productive sand pinches out or is practically dry. The gravity of the oil varies from 13° to 17° B., apparently being heavier toward the outcrop of the beds and lighter down the dip. A variation in gravity between 14° to 15° along the strike is also noticeable, the southernmost wells producing the lighter oil.

Although zone B is the first productive zone encountered in the wells, there is above it a tar sand called the "Big Gumbo," which is penetrated by nearly all the wells from the Union south to the line of Associated wells along the northern side of sec. 36. This gumbo sand, as the name implies, carries a heavy oil or tar, which has so far not been utilized in any of the wells. In the region of the Caledonian wells at the western edge of the developed territory and farther up on the dip there is still a higher oil sand, but this also is nonproductive.

Below zone B are three well-defined oil sands throughout the region from the Union wells southward as far at least as the north edge of sec. 36. The uppermost of these sands varies from 10 to 50 feet in thickness, while the second is usually somewhat thinner. Hard shells are often associated with these lower sands, but in many of the wells blue shale is apparently the only parting. In some instances the sands below zone B are divided into three or four minor layers which show little regularity in thickness between the different wells.

The gravity of the oil in the zone below zone B is usually about the same as that in zone B, but in the Caledonian and Angelus regions an oil sand carrying 17° B. petroleum is found immediately underlying zone B. It is barely possible that this may be the equivalent of the light-oil sand in the region of the Coalinga Pacific and other wells of that same area, but it is the opinion of the writers that there is no direct connection between beds carrying the light oil in this southern part and the beds carrying oil of the same gravity in the region north of Los Gatos Creek.

In the region of the Wabash and Inca properties the oil sands are apparently the most regular of the Westside field, but on each side of this particularly regular zone the variations in the sands is considerable from well to well, both along and across the strike of the beds.

A persistent stratum of sulphur water sand is encountered in most of the wells between the gumbo or tar sand and zone B. This sulphur sand varies in thickness from about 10 to 20 feet, although in one of the Wabash wells it has apparently split up into two sands separated by shale, each sand member being somewhat less than 10 feet in thickness. In certain wells of this area the sulphur sand contains traces of oil, especially in those wells along the north side of sec. 36 and in some of the Union wells.

The formations above the zone of the gumbo or tar sand usually contain two or more water sands. In most of the wells the first sand is encountered at depths under 200 feet, but between this sand and the gumbo the occurrence of water is irregular. In some of the wells water sand approximating 50 feet in thickness is encountered 200 feet below the first water sand, whereas in wells near by the second water sand may be only 10 feet thick and may be separated from the first sand by one or two other strata carrying water. The water from all of those sands is considerably mineralized and is not fit for domestic uses.

Typical well log in Associated-Caledonian-Union area.

	Feet.
Shale	150
Water sand	20– 30
Shale with some dry sand or gravel	200
Water sand	20– 50
Blue shale with some dry sands and occasionally some water sand	600
Tar zone, zone A	8– 50
Blue shale	20–100
Sulphur-water sand	20
Blue shale with occasionally fine sand layers. (The water is generally shut off in the upper part of this shale zone. Such a proceeding is doubtless flooding the gumbo sand, but as this tar sand is not believed to be productive in any part of the field the flooding is doing no harm.)	100–200
Zone B and various oil sands of more or less importance, the whole being thinnest near the outcrop and thickening gradually down the dip	100–225

One of the Caledonian wells was drilled to a depth of over 2,300 feet, but from the depth of something over 700 feet it passed through the usually unproductive Eocene brown and blue shales (Tejon formation) yielding warm salt water of 110° F. near the bottom. Sulphur water was also encountered at about 1,600 feet in this well, and a little greenish oil of over 17° gravity was encountered near the 1,000-foot mark. The base of the productive measure in this area is believed to be marked by a persistent stratum of salt or brackish water, which is encountered in wells drilled into the underlying Tejon shales.

PRODUCT.

The product in the wells so far drilled in this area comes from zone B, the Jacalitos (upper Miocene) formation. The daily production of the individual wells varies from about 400 barrels in the deeper wells to 50 or 60 barrels in the shallower. Many of the wells flow at first, and some of the deeper ones continue to flow for two or three years, but most of the wells are pumped after the initial head of gas has blown off. Much sand accompanies the oil, especially in the shallower wells, running as high as 50 per cent at first in some of the wells. Large amounts of gas are produced by most of the wells. The gravity of the oil varies from 12° B. in the shallow wells, those up on the dip, to 17° for the deeper holes. Three sands are recognized in the productive zone, the upper one yielding the lightest oil.

AREA BETWEEN WALTHAM CREEK AND SAN JOAQUIN VALLEY COAL MINE.

LOCATION.

The area treated in the following paragraphs comprises the territory lying between the Cretaceous-Vaqueros (lower Miocene) contact (which extends northwestward from Alcalde) and the valley floor west of Coalinga, and between Waltham Creek and the reigon of the San Joaquin Valley coal mine in the NW. ¼ sec. 26, T. 20 S., R. 14 E. A portion of this region, however, that in which the wells of the Sunnyside and Westlake-Rommel oil companies are situated, is omitted and will be considered separately.

The oil companies operating within this region include the Mount Hamilton, Commercial Petroleum, West Coalinga, Coalinga Zenith, Summit, Z. L. Phelps, Blaine, Yellowstone, Coalinga Southern, Section Six, T. C., Lucile, Shreeve, St. Francis, Associated, Southern Pacific Railroad, and some others not yet prosecuting development work.

GEOLOGY.

The formations involved in the geology of this area comprise the Knoxville-Chico (Cretaceous, sandstone and shale), the Tejon (Eocene, sandstone and shale), a series of sandstones overlain by soft shale which are believed to be largely of Vaqueros (lower Miocene) age, the Jacalitos (early upper Miocene, sandstone, conglomerate, and shale), and the Etchegoin (late upper Miocene, sand and clay shale).

The Knoxville-Chico rocks (Cretaceous) consist of dark thin-bedded shale with some sandstone, the latter in places carrying the characteristic brown concretions. It outcrops west of the area under discussion and extends in a northwesterly direction into the hills south of Los Gatos Creek. In the main the Cretaceous beds are steeply tilted, forming a monocline with an approximate dip of 60° SE. They carry no oil in commercial quantities, but are believed to yield the water in the Henshaw and West Coalinga wells.

The Tejon (Eocene) formation consists largely of medium-grained sandstone with some intercalated shales at the base and a considerable thickness of shale at the top. It occupies a small area in the SW. ¼ sec. 26, T. 20 S., R. 14 E., just south of the San Joaquin Valley coal mine. With the exception of this small outcrop the Tejon in this area is entirely covered by the later beds, which overlap it from the east and south. The basal Tejon overlies the Cretaceous apparently conformably and dips northeastward at an angle of about 30° and is itself in turn overlain unconformably by the Miocene beds.

Unconformably overlying the Knoxville-Chico (Cretaceous) and the Tejon (Eocene) just described is a series of beds consisting of about 250 feet of sandstones and over 100 feet of soft dark-blue shale.

These beds are known to be Vaqueros at the base, but the age of the uppermost member, the shale, is unknown. The latter, however, may possibly be the equivalent of the "Big Blue" in the northern end of the Coalinga field, although in the area under discussion it has been mapped with the Vaqueros, and in the Eastside field it is included in the Santa Margarita. The basal sandstone of the Vaqueros formation may be traced from a short distance south of the San Joaquin Valley coal mine southward across the northwest corner of sec. 35, T. 20 S., R. 14 E., along the western edge of the same section, into the middle of the NW. ¼ sec. 2, T. 21 S., R. 14 E., thence southeasterly to the bottom of the canyon near the middle of the south line of the SE. ¼ sec. 2. Thence it passes westward below and north of the summit of the big ridge which extends several miles northwesterly from Alcalde. Near the San Joaquin Valley coal mine the Vaqueros overlies the Tejon (Eocene), but near the northwest corner of sec. 35 it crosses the contact between the Knoxville-Chico (Cretaceous) and the Tejon, and from there southwestward it overlies the Knoxville-Chico. The contact between the Knoxville-Chico and the Tejon is believed to extend southeasterly underneath the Vaqueros diagonally through sec. 35, T. 20 S., R. 14 E., and diagonally through sec. 1, T. 21 S., R. 14 E. Its course from the latter region is not definitely known, but can be surmised, as is stated elsewhere (p. 118). The tracing of this contact beneath the Vaqueros is important because of the fact that the oil is derived from the Eocene shale, and it is believed that wherever the Vaqueros or other formations overlie the Tejon they will be found more or less petroliferous, while in the areas where the same formations overlie the Knoxville-Chico they will be found barren or containing only such petroleum as has migrated along the strata from areas underlain by the Tejon. It is worthy of note in this connection that along practically the whole extent of the outcrop of the base of the Vaqueros from the San Joaquin Valley coal mine southward to the southern part of sec. 2, T. 21 S., R. 14 E., the basal beds are more or less petroliferous. The indications are so strong in certain places, notably in the SE. ¼ sec. 2, that tunnels have been run into the base of the Vaqueros sands with the expectation of obtaining petroleum in commercial quantities.

Westward from the southeastern part of sec. 2 the basal Vaqueros sands become less and less petroliferous until on the flanks of the ridge spoken of as extending northwestward from Alcalde the beds show no indications of petroleum.

The description of the geologic section exposed on the surface along a line extending from the middle of the southern line of sec. 2, T. 21 S., R. 14 E., in Anticline Canyon, to the top of Flag Hill (located in the SE. ¼ sec. 1, T. 21 S., R. 14 E., and shown as the triangulation station on the topographic map) and thence in a direct line to the Lucile well covers all the formations of the area under discussion; this section is based upon a detailed surface traverse and in a general way upon the well logs of secs. 6 and 36 to the northeast:

Geologic section from Anticline Canyon in S. ½ SE. ¼ sec. 2, T. 21 S., R. 14 E., to Lucile well (beginning with lower strata).

[Dip approximately 20° NE.]

Vaqueros (lower Miocene). Beds 1–4.

Bed 1. Much-discolored and rusty-yellowish sand and soft sandstone, highly charged with petroleum in the immediate vicinity of Anticline Canyon, and about 150 feet thick. Not yet pierced by any of the wells in the sec. 6 area, but is believed to be a rich oil-bearing sand throughout its entire thickness. Represents the basal part of zone D of the developed territory.

Bed 2. Largely gypsiferous sand, with a hard fossiliferous layer at base. The fossils, which occur abundantly in Anticline Canyon a short distance below the southern line of section 2, are believed to be from the same bed as the fossil "clam" shells thrown out in the sand from the bottom of Lucile well No. 1. About 150 feet thick; probably represents parts of zones C and D in the Eastside field.

Bed 3. Soft sand with pebbly layers and occasional hard, coarse, rusty, sandstone strata, which would be called "sandstone shell" if encountered in the wells. About 200 feet thick, and is also a part of zones C and D. Beds 2 and 3 apparently thin out slightly toward the valley, as the thickness disclosed by the well logs is somewhat less than that obtained by calculation from the surface outcrops.

Bed 4. Largely clay, about 250 feet thick, and may be the equivalent of the "Big Blue" in the Eastside field.

Jacalitos (early upper Miocene). Beds 5–11.

Bed 5. Largely pebbly sand overlain by thin-bedded sand and soft sandstone. Bed of fossils, largely *Zirphæa*, at top; believed to be the ones reported in both the Shreeve and Lucile logs. These are an important tie line, not only in this particular area, but also throughout the Coalinga district. Bed believed to be the same as that which rests upon or near the Tejon, west of that part of the Westside field lying north of the San Joaquin Valley coal mine, and believed to be of upper Miocene age. Zone B, in the wells of the south and central parts of the Westside field, is between 100 and 200 feet in thickness.

Bed 6. Above the fossil bed are some coarse gray sand layers. Well in the NE. ¼ SW. ¼ sec. 12, T. 21 S., R. 14 E., begins in this zone of sand.

Bed 7. Clay; apparently thickens somewhat toward the valley, especially between the Shreeve and Lucile wells.

Bed 8. Persistent layer of soft pebbly sandstone, recognized in both the Shreeve and Lucile well logs.

Bed 9. Ten-foot layer of clay.

Bed 10. Another pebbly sandstone layer, apparently not so persistent as bed 8.

Bed 11. Important and widespread soft blue clay.

Etchegoin (uppermost Miocene). Beds 12–17.

Bed 12. Brown sand at the base, 10 feet of hard sandstone, then a layer of sand, another layer of sandstone, and finally soft sandstone at the top.

Bed 13. Soft blue shale, 15 to 200 feet thick.

Etchegoin (uppermost Miocene). Beds 12–17—Continued.

Bed 14. Coarse brown to greenish pebbly sand at base, overlain by coarse brown sand, containing numerous large fossil sand dollars, *Echinarachnius gibbsi* Rémond. About 125 feet thick.

Bed 15. This is sand and soft sandstone, pebbly at the bottom, and contains numerous fossils. It is known as a fossil bed in the wells in some parts of the field and contains such species as *Pecten oweni* Arnold, *Glycymeris*, etc. It is the *Glycymeris* zone not far above the base of the Etchegoin formation.

Bed 16. This layer is of bluish clay, about 100 feet thick.

Bed 17. From the top of bed 17 down to the detritus-covered valley floor in the vicinity of Lucile well No. 1 the beds exposed are largely coarse sands with occasional pebbly layers. Toward the edge of the hills some of the beds contain cobbles of considerable size and fossils indicating the same horizon as the *Pecten coalingaensis* zone, frequently mentioned in the discussion of the geology as near the top of the Etchegoin. Usually spoken of by the drillers as surface formation, as they appear to be largely incoherent and of a heterogeneous character. Uppermost possibly represent part of the Paso Robles formation.

STRUCTURE.

The main structural feature is, of course, the great southeastward dipping monocline that extends from the top of Curry Mountain and Juniper Ridge to the middle of Pleasant Valley. There are, however, one or two local lines of disturbance within the area which are worthy of mention. The most important begins in the Knoxville-Chico rocks (Cretaceous) somewhere northwest of sec. 2, T. 21 S., R. 14 E., and passes southeastward apparently almost coincident with the bed of Anticline Canyon. From the south line of sec. 2 to the middle of the E. ½ SW. ¼ sec. 12 this line of disturbance has the character of a southeastward-plunging anticline. The dips on the east are apparently about 20°, while those toward the south vary from 8° or 10° in the region immediately south of sec. 2 to 30° or 40° in the southern part of the SW. ¼ sec. 12. At a point a short distance west of the east line of the SW. ¼ sec. 12 the line of disturbance bends abruptly and passes almost due east for nearly three-fourths of a mile. Along the east-west portion the disturbance takes the form of a fault, although the beds in a general way dip away on both sides of the fault line. The line of fracture may be traced from the dome of the anticline in the eastern wall of Anticline Canyon, in the eastern part of the SW. ¼ sec. 12, to a point less than one-fourth mile northeast of the Commercial Petroleum Company's well No. 1 in the SE. ¼ sec. 12. The beds on the southern side of the fault are inclined in a southerly direction with the dips varying from 60° or 70° near the fracture to 35° or 40° some distance south of it. North of the fracture the beds dip about 20° NE. and abut sharply against the steep south-dipping beds. From the eastern line of the SE. ¼ sec. 12 the line of fracture apparently bends abruptly toward the southeast and dies out beneath the superficial deposits of Alcalde Canyon.

A minor disturbance, probably intimately connected with the one just described, is developed in an east-west ridge in the NE. ¼ sec. 7, T. 21 S., R. 15 E. An examination of the surface geology of this region, beginning at the railroad cut in the NW. ¼ sec. 8, T. 21 S., R. 15 E., discloses, first, coarse sandstone beds dipping N. 35° E., at angles of 10° to 50°; westward from here along the crest of the ridge dips of N. 25° W. 16° are encountered; then dips of 20° a little farther toward the west, and finally, where the strike of the bed swings around toward the northwest, dips as high as 40°. Northwest from this maximum dip the beds drop to 30° northeast and finally to the prevailing dip of 18° to 20° along the western side of sec. 6.

A third line of disturbance is visible in the small bluff on the northwest side of Alcalde Canyon immediately north of Alcalde station. This is a sharp anticlinal fold in gray and brown shale with a dip of 20° S. 53° W. on the one side, and of 70° N. 55° E. on the other. Mount Hamilton well No. 1 is drilled practically on the axis of this anticline less than one-fourth mile from the bluff mentioned. An examination of the territory northwest of the Mount Hamilton well, embracing the territory along the contact between the Knoxville-Chico and the Tejon, discloses dips that apparently indicate a northwestward continuation of the anticline as far as the SE. ¼ sec. 10, T. 21 S., R. 14 E. The beds in this region are lying so nearly horizontal and have been so affected by landslides that it is impossible to determine definitely the course of the line of disturbance. This structural feature, however, has no apparent influence whatever upon the oil-bearing beds, but is described simply to indicate the localization of the forces producing folding in the beds.

Still a fourth line of disturbance enters the area under discussion in the southwestern part of sec. 7, T. 21 S., R. 15 E. This is a syncline which is prominently developed farther south and has been described in the discussion of the area south of Waltham Creek (p. 66). In the southwest corner of sec. 7 this syncline produces dips of 40° S. 20° W., while a short distance south the same bed dips 30° nearly due east, a little farther south 25° in the same direction, and still farther south 20°. This syncline is apparently associated with the Anticline Canyon flexure, but the relations between the two are obscured at the critical point along the south line of sec. 7 by the detrital material of Waltham Creek.

In connection with the folding and faulting which has taken place in sec. 12 it might be well to amplify the description of the geology in the vicinity of the Commercial Petroleum well No. 1 in the southeast corner of the SE. ¼ sec. 12, T. 21 S., R. 14 E. A section along the surface of the ridge northward from this well shows the following strata, all dipping approximately due south about 60°:

Section in Miocene north from Commercial Petroleum Company's well No. 1, sec. 12, T. 21 S., R. 14 E.

	Feet.
Soft sand, to	30
Pebbly sand	40
Soft sand	180
Coarse sand with hard dark layers ("shells")	240
Fine pebbly sand (dipping due south 60°)	255
Alternating coarse sandstone and pebbly sandstone beds with a particularly hard brown sand layer at the base	320
Soft blue shale and sandy shale	620
Coarse pebbly sand, the last half hard and containing silicified wood fragments (dip is 50° south)	710
Gray sand with one or two hard streaks	760
Soft blue gypsiferous shale	790
Medium to coarse gray sandstone	820

At 820 feet is the fault line extending in a direction S. 80° E. The downthrow is on the north and is probably at least 200 feet. The beds along the trace of the fault are of a purplish and pink tint, this discoloration probably being due to petroleum which has seeped up along the fault. A comparison of the above surface section and the log of the Commercial Petroleum well indicates the reason for the discrepancy between this well log and those of the wells in the sec. 6 area. In the Commercial Petroleum well the beds penetrated dip about 60°, while in the sec. 6 area the beds dip less than 20°. The water which occurs in the Commercial Petroleum well is probably of local extent and is to be associated with the fault line which apparently is cut by the well near the latter's junction with the oil sand. It is the belief of the writers that it would be impossible to put down wells in this faulted area and obtain the same or even approximate results in any two. The region about the corners of secs. 12 and 13, T. 21 S., R. 14 E., and secs. 7 and 18, T. 21 S., R. 15 E., is the center of a number of complex disturbances, which, it is believed, have locally so complicated the underground geology as to make the exploitation of the oil sands difficult if not impossible.

GEOLOGY OF THE WELLS.

The wells of this area lie for the most part in the angle where the formations bend from a strike of south and southeast to a strike of east or east-southeast. This change in strike is caused by the line of disturbance which passes down Anticline Canyon and bends abruptly east in the SW. ¼ sec. 12, T. 21 S., R. 14 E. The eastward continuation of this line of disturbance across sec. 7, T. 21 S., R. 15 E., is the cause of the abrupt turning to the east of all of the formations on the flanks of the great monocline on the west side of Pleasant Valley. It will be noticed by an examination of the contour map (Pl. II) that the formations have a practically uniform dip of about 18° or 20° down to the edge of the more pronounced hills. At the edge of the hills the dip flattens out to an angle of about 5° or 6°. It should be observed in this connection that the topography in a general way reflects this change in dip. This is an important item to remember, as in other parts of the field where there are no wells and in which surface outcrops are lacking it may be possible to judge in a general way of the position of the underground formations by a critical examination of the topography of the region under observation. As a result of the bowing of the strata the dips are apparently steepest in sec. 36, but flatten out and become more regular north of this area. In the southern part of sec. 6 and also the northern part of sec. 7 the dips are very steep at the surface outcrop. The locus of the steep dip apparently extends from the surface underground in a northerly direction and has its maximum effect on the oil sands in the NW. ¼ sec. 6 and the SE. ¼ sec. 36. Details of the change in dips and strike are indicated by contours on the map (Pl. II) and will not be discussed further here.

All of the wells within this area start down in the soft surface sands and clays, which, below the uppermost superficial stratum, are believed to belong to the Etchegoin or possibly the Paso Robles formation. Before reaching the uppermost oil zone (zone B), the wells pass through four or five well-defined zones of sandstone with as many interbedded layers of soft blue shale. Many of the sands carry pebbles up to the size of a marble, and some of the blue shales are also pebbly. Water sands are encountered at various depths, some of them producing large quantities of more or less mineralized water. The Lucile well No. 1 and the West Coalinga well No. 1 produce a great deal of water, but from entirely different rocks, the first from the Jacalitos (upper Miocene) the latter probably from the Knoxville-Chico (Cretaceous). Some very hard sandstone shell layers are encountered in the wells and in one or two places these appear to be rather persistent laterally. The hard layer reported as the "Big Shell" in some of the wells is apparently not the stratum so designated in others.

The first oil zone (zone B) varies in thickness from about 60 to 150 feet. In some of the wells it is reported as nearly solid sand, while in others it is a zone of alternating sandstone and shale. Oil or gas, or both, are reported from it in all of the wells except Shreeve No. 1, but it is believed that indications of petroleum must have been found in this well and overlooked by the driller, or else they were not considered of enough importance to record in the log. So far as known none of the wells in this area produce from this zone. The individual sands of zone B vary from fine-grained thin-bedded layers intercalated with sandy shale to coarse conglomeratic sand carrying small cobbles.

As previously mentioned, this zone may be studied in the east wall of the canyon running up to the Henshaw water well (SW. ¼ sec. 35, T. 20 S., R. 14 E.) about half a mile southeast of this well.

Oil zone B is underlain by a persistent stratum of mineralized water, either salt or sulphur or both, in nearly all the wells. In some this flow of water was encountered at the base of a hard sandstone shell underlying the oil strata, but in others it is reported in the lowest oil sand of the zone. Oil zone B is separated from the lower or zone D by between 150 and 200 feet of shale and shell. Some water sands and tar sands are reported in the space between zones B and D in some of the wells, but these do not appear to be very persistent. Only three of the wells have so far penetrated zone D and these touch only its uppermost sands. The reason for this is generally because the gas pressure is great enough either to make the well flow or to fill it up with sand. The uppermost beds of zone D are fine grained and carry oil of fairly light gravity. Oil of 32° B. has been reported in one of the wells, and the gravity of all the upper beds seems to range from this down to 26° B.

Below the zone of light oil sands is a coarser sand carrying fossil shells and believed to be the same as the bed at the base of bed 2 in the section on page 101. The oil from this lower zone is much heavier than that from the upper, averaging about 16° or 17° B.; the production also is very much greater from the lower sand than from the upper finer sands, and is, therefore, tapped wherever possible. It is the belief of the writers that this lower oil sand will furnish long-lived wells, for holes that simply tap its uppermost layers are very productive and the 150 or 200 feet of sands that are believed to underlie the tapped bed are doubtless heavily impregnated with oil.

SEC. 2, T. 21 S., R. 14 E., AND VICINITY.

GEOLOGY OF THE WELLS.

Underground conditions in the E. ½ sec. 2, T. 21 S., R. 14 E., and in the southern part of sec. 35, T. 20 S., R. 14 E., have been tested by the wells of the Sunnyside Oil Company (Henshaw water well) and the Westlake-Rommel Oil Company. The wells penetrate the northeast-dipping beds of the Vaqueros formation (lower Miocene), which overlie the steeply tilted Knoxville-Chico (Cretaceous) strata exposed at the surface toward the west. The oil in this area is believed to have percolated along the basal (zone D) sands from the east, where these sands overlie the shales of the Tejon (Eocene). Only four wells have so far been put down in this area; three were sunk several years ago by the Westlake-Rommel Oil Company, and one (the Henshaw water well) was put down by Captain McClurg for the Sunnyside Oil Company in 1897. The logs of these wells indicate that the petroliferous zone is from 100 feet to 120 feet thick and consists of medium-grained sands interbedded, especially toward the middle of the zone, with fine clays and harder sand layers. The sand carries a little heavy oil and in the Westlake-Rommel wells is said to have yielded no gas. This lack of gas would be expected in an area so close to the outcrop of the oil sands where the gas would have an opportunity to escape from the petroliferous beds. Water is found associated with the oil in the uppermost layer of this zone in one of the wells and is found abundantly in the sands just beneath the oil zone. In addition to the four wells mentioned, tunnels were run in on the outcrop of the oil sands in the E. ½ sec. 2, but did not obtain enough oil to pay for their operation.

It is believed that the Henshaw well obtains its water from a sand in the Knoxville-Chico (Cretaceous), as the depth at which the sand is penetrated is considerably lower than the base of the Vaqueros formation. As the Knoxville-Chico beds in this region are highly tilted, wells will be able to tap the Henshaw water sand along a narrow band only. As the strike of the Knoxville-Chico is here about east-northeast, it is believed that this band strikes in a direction north-northwest or south-southeast of the Henshaw well.

PRODUCT.

The daily yield of the individual productive wells in the area between Waltham Creek and the southern part of sec. 36 ranges from about 100 barrels in those on the dip to about 800 barrels in the deeper holes. An initial production of over 1,500 barrels a day is said to have come from one of the wells. Oil of 26° B. gravity is yielded by sands at the top of the lower zone (zone D), and as high as 175 barrels of oil a day is said to have been produced by one well from these sands alone. Below the light oil sands are coarser and more productive layers which yield the bulk of the oil for this territory. The gravity of the petroleum from this last horizon is between 16° and 17° B. The oil in the light oil sands is brown; that in the zone of heavier oil is black.

KREYENHAGEN FIELD.

LOCATION.

The region south of Coalinga as far as Dudley, Kings County, including the Kettleman and Kreyenhagen Hills and Reef Ridge, has been known for many years as the Kreyenhagen oil district. For the sake of brevity of discussion in the present report this territory has been included as a part of the Coalinga district and has been divided into two fields, the Kreyenhagen field and the Kettleman Hills field. The area discussed as the Kreyenhagen field lies on the southeastern flanks of Reef Ridge and extends from the general region of Jacalitos Creek to Dagany Gap, 3½ miles southeast of Dudley. The area in which oil development has been carried on constitutes a narrow band between Canoas Creek and the region of Big Tar Canyon.

GENERAL GEOLOGY AND OCCURRENCE OF OIL.

Reef Ridge and the region immediately adjacent to it both southwest and northeast lies on the eastern flank of the great monocline of rocks which forms the main Diablo Range. The formations involved in the geology are the Knoxville-Chico (Cretaceous, conglomerates, sandstones, and shales), the Tejon (Eocene, sandstones and shales), the Vaqueros (lower Miocene, sandstone and shale), the Santa Margarita (upper middle Miocene, shale), and the Jacalitos (upper Miocene, sandstone, shale, and gravel). The oil, as in the region of the Coalinga field proper, is believed to have originated in the shales of the Tejon formation, but has migrated to the underlying sandstones of the Tejon, into sands interbedded with the shales of the Tejon, and into the overlying Vaqueros sandstone. Evidence of the petroliferous character of the Tejon and Vaqueros is found in numerous tar springs which emanate from those formations at various points within the area under discussion. Such, for instance, are those in Canoas Creek, which come from the upper part of the Vaqueros; those on or near the Clark ranch farther south in the vicinity of Garza Creek in the same formation as the latter; the famous tar spring in Big Tar Canyon, which comes from the upper part of the Tejon; and the springs in Little Tar Canyon and north of it, which emanate from the upper part of the Tejon. Numerous other seepages and springs are found along the outcrop of the Tejon and Vaqueros; but within the area mapped none, to the knowledge of the writers, are found farther north than Canoas Creek nor farther south than the head of Little Tar Canyon.

Indications of petroleum are found in the basal shale layers in the Tent Hills anticline, 2 miles southeast of Dudley, but no true seepages are known between the one in Little Tar Canyon and Sulphur Spring in the Devils Den district. The Castle Mountain fault, which cuts off the Tejon and Vaqueros near the head of Little Tar Canyon, is believed also to eliminate these same formations under the Santa Margarita southward for a considerable distance below the head of Little Tar Canyon. Owing to the steep dip in the formations along Reef Ridge the petroliferous zone is necessarily very narrow. The extent of the zone in which it seems possible that productive wells may be put down is shown on the map (Pl. I). Water accompanies the oil in all of the seepages along this belt and has caused the failure of many of the test holes that have been put down in the area.

GEOLOGY OF THE WELLS.

The wells in the Kreyenhagen field may be divided into two groups; those which have been sunk in the Tejon (Eocene) formation, and those which start in strata above or younger than the Tejon. The wells in the first group, enumerated from north to south, include those of the Kreyenhagen Oil Company, Kings County Oil Company, Consolidated Oil and Development Company, Baby King Oil Company, and Avenal Land and Oil Company. The wells in the second group enumerated in the same direction include those of the Black Mountain Oil Company, Kings County Oil Company, St. Lawrence Oil Company, and that of the El Cerrito Oil Company, formerly known as the Anderson well.

Tejon formation.—The two wells of the Kreyenhagen Oil Company are located on Canoas Creek in the SE. ¼ sec. 32, T. 22 S., R. 16 E. Both wells start in the shale in the upper part of the Tejon, the southermost, well No. 1, beginning lowest in the formation. This well (No. 1) penetrated 650 feet of dark-colored shale, finding water at 125 and at 400 feet, and ended in 10 feet of oil sands.

An examination of the geology immediately south of this well indicates that the oil sand is very much thicker than indicated; just how far below the shale the sand is impregnated it was not possible to determine accurately, but on the surface the sand showed signs of petroleum for a thickness of over 100 feet. Well No. 1 is said to have yielded about 15 barrels a day at the start, soon falling to 5 or 6 barrels. The product is said to be a light-green oil, gravity between 37° and 38° B. No water accompanied the oil. Well No. 2 of the same company is located north of and higher in the formation than well No. 1. It is said to have found traces of oil at 1,000 and 1,100 feet and to have attained a depth of about 1,200 feet, at which point water was encountered. This last well never produced commercial quantities of oil.

The Kings County Oil Company sunk a well in the SW. ¼ SW. ¼ sec. 3, T. 23 S., R. 16 E. This location implies that the well started somewhere about the middle of the band of the Tejon formation as developed in this vicinity. The well is said to have passed through black shale, blue sandstone, and brown sandstone containing oil, but was abandoned on account of water.

The Consolidated Oil and Development Company sunk two wells in the Tejon (Eocene) formation in the NE. ¼ sec. 10, T. 23 S., R. 16 E. One of the wells attained a depth of 1,100 feet and is said to have obtained a good showing of 20° B. amber-colored oil at a depth of 1,050 feet. The difference in gravity between this oil and that obtained from the same formation in the Kreyenhagen well is not easily explained.

The well of the Baby King Oil Company is located in the canyon of the first stream west of Big Tar Canyon, immediately behind Reef Ridge, in the NE. ¼ sec. 11, T. 23 S., R. 16 E It starts in strata lying near the contact between the Tejon (Eocene) and Vaqueros (lower Miocene) formations. It is said to have struck oil of 30° B.

gravity at 400 feet, and oil of 18° B. gravity at 1,100 feet; a short distance below this last point flowing water was encountered. At the time of the writer's visit, in September, 1907, the well was flowing about half a miner's inch of water, accompanied by occasional blebs of black heavy oil and some gas.

The Avenal Land and Oil Company has two wells in the E. ½ E. ½ sec. 18, T. 23 S., R. 17 E., not far from the famous tar spring in Big Tar Canyon. Well No. 1, the westernmost of the two, starts down in the soft oil-stained sand beds of the Tejon (Eocene), or possibly Vaqueros (lower Miocene), immediately underlying the lowest hard sandstone bed of the Vaqueros. The log of this well is as follows:

Log of well No. 1, Avenal Land and Oil Company, E. ½ E. ½ sec. 18, T. 23, S., R. 17 E.

	Feet.
Adobe	20
Oil sand with water	70
Blue water sand	140
Clay	235
Shale	521
Oil sand	555
Shale	590
Sand showing traces of oil	635
Shale	802
Blue clay	900
Sand with traces of oil (not finished)	984

This well is said to have yielded less than 2 barrels a day of dark-colored 28° B. oil. Well No. 2 starts well down in the Tejon and is said to have gone through soft sand to 1,045 feet, where a productive sand was encountered. It yielded some oil when pumped by a bailer.

Formations above the Tejon.—The Black Mountain Oil Company sunk two wells in the SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 16 E. Both start in the dark shale of the Santa Margarita formation and obtain their oil from the top of the Vaqueros sandstone. The log of well No. 1 of this company is as follows:

Log of well No. 1, Black Mountain Oil Company, SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 16 E.

	Feet.
Dark-colored shale	80
White sand	85
Dark-colored shale	400
Light-colored shale	550
Shale and sand with oil	570
Light-colored shale	640
Oil sand	660
Shale	700
Oil sand	720

This well is said to have produced 5 or 6 barrels of black, 18° B. oil. The second well is located 600 feet north of No. 1, but no data concerning it are available.

The Kings County Oil Company sunk a well in the SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E., which is believed to start toward the bottom of the Santa Margarita (upper middle Miocene) and to obtain its oil from the Vaqueros (lower Miocene). The log of this well is as follows:

Log of well of Kings County Oil Company in SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E.

	Feet.
Clay and soil	12
White shale	29
Black shale	65
Black sand	67
Black shale	90
Hard gravel (heavy oil at 240 feet)	120
Black shale	275
Gravel	285
Black shale	410
Blue sand rock	450
Water sand	490
Blue sand rock	540
Sand	556
Clayey sandstone	600
Black shale	660
Clayey sandstones	696
Hard shale	720
Hard rock, sandstone predominating	950

Another well was also started by the same company but was never finished.

The St. Lawrence Oil Company is said to have sunk a well in the SE. ¼ NE. ¼ sec. 12, T. 23 S., R. 16 E., which encountered oil near the bottom. This well doubtless began in the shale of the Santa Margarita and penetrated the oil sands at the top of the Vaqueros (lower Miocene).

A. M. Anderson and associates (El Cerrito Oil Company) have been drilling the past summer on a well in the NW. ¼ sec. 14, T. 23 S., R. 17 E. The well starts near the contact between the Etchegoin (upper Miocene) and Paso Robles (Pliocene-Pleistocene) formations, and is said to have been located on the evidence of a supposed oil sand outcrop a few hundred feet south of the well site.

KETTLEMAN HILLS FIELD.

LOCATION.

Development work within the Kettleman Hills has been confined to their northern portion, all the wells started having been put down on the flanks of the hills at some distance from the axis of the Coalinga anticline, which runs parallel with and east of the topographic axis of the hills.

GEOLOGY AND INDICATIONS OF OIL.

The formations that rise to the surface in the anticline are the Etchegoin and the Paso Robles, described fully on pages 46–61. The structure of the hills is that of a simple arched anticline, with low dips toward the axis and steeper ones toward the flanks. The maximum dip on the northeastern flank is about 31°, that on the southwestern flank 45°.

One of the Government land surveyors who visited the Kettleman Hills over twenty years ago informed the late Mr. W. P. Kerr (who informed the senior author) that he had seen what he supposed was an oil seepage in the northeastern flank of the hills in the southeastern part of T. 21 S., R. 17 E., or the northeastern part of T. 22 S., R. 17 E. Neither Mr. Kerr nor the senior author, who visited this locality in 1907 and made a careful examination, were able to find any traces of an oil seepage in this region, although places where mineral waters have oozed from the rocks in the rainy season were noted in several instances. It is believed that the Kettleman Hills offer no direct surface evidence of petroliferous deposits.

GEOLOGY OF THE WELLS.

Seven or more wells have been put down in the hills and none of these have been successful, but owing to their position and comparatively slight depth they have made no adequate test of the territory. (See p. 120 for conclusions concerning future development.) Two wells, the Gibbs and Oceanic, are on the northeastern flank of the anticline; the other five are on the southwestern flank. None are within the area outlined as possibly productive on the map (Pl. I).

Following are descriptions of the wells that have been put down in the Kettleman Hills:

Gibbs Oil Company, located in eastern part of the NW. ¼ sec. 28, T. 21 S., R. 17 E., farthest north of any in the Kettleman Hills. Starts in beds near the top of the Etchegoin (upper Miocene) formation about 1 mile east of the axis of the Coalinga anticline.

Oceanic Oil Company's well; located in the NW. ¼ sec. 1, T. 22 S., R. 17 E., on northeastern flank of Coalinga anticline on one of the spur ridges running northeast from the main Kettleman Hills divide. Starts in the uppermost blue-gray sands of the Etchegoin; said to have penetrated blue sands and shales and to have yielded large quantities of water; depth, 950 feet.

Stanislaus Oil Company's well; located in the NW. ¼ sec. 4, T. 22 S., R. 17 E. Starts in beds well up in Etchegoin formation, a little less than a mile southwest of the Coalinga anticline; is said to have attained a depth of about 1,000 feet without encountering any oil.

Iowa Oil Company's well; located in the SW. ¼ sec. 4, T. 22 S., R. 17 E., not far distant from and on the same ridge as that of the Stanislaus Oil Company. Conditions in the two wells are practically the same and results obtained were similar.

Florence Oil Company's wells; both located in the NW. ¼ sec. 15, T. 22 S., R. 17 E. On the southwestern flank of the Coalinga anticline about a mile from the axis; near the surface penetrate strata at the bottom of the Paso Robles formation. Are said to have attained a depth of 720 feet and to have encountered considerable gas but no oil.

Esperanza Oil Company's wells; both located in the SW. ¼ sec. 14, T. 22 S., R. 17 E. One attained a depth of 1,100 feet but was abandoned on account of water; the other reached 840 feet when drilling operations were suspended. Start in the uppermost beds of the Etchegoin formation, on southwestern flank of the anticline something over a mile from the axis.

Stockton Oil Company's well; located in the NW. ¼ sec. 30, T. 22 S., R. 18. E., farthest south of any test well in the hills. Starts in beds near the contact between the Etchegoin and Paso Robles formations, on southwestern flank of the anticline about 2 miles distant from the axis. Is said to have attained a depth of 670 feet, with no results in the way of gas or oil.

FUTURE DEVELOPMENT.

GENERAL STATEMENT.

The conclusions here to be discussed as to the course that future development will take in the Coalinga district are based on the belief that the petroleum is originally derived from the shales of the Tejon (Eocene) formation and that on migration it collects both in the sands interbedded with these shales and in the porous portions of the overlying Miocene. All of the conditions indicate that this belief is well founded and is equivalent to the truth.

Several requisite factors enter into the question of the accumulation of the petroleum and the possibility of its extraction in commercial quantities. Among these are the following, briefly stated:

(*a*) An adequate thickness of the shales of the Tejon (Eocene) to yield commercial quantities of oil.

(*b*) A cause for the migration of the oil from its source in the organic shales. This cause is believed to be supplied by the tendency of oil to migrate by diffusion through certain media, such as dry shales; it may be and doubtless is in certain instances augmented by hydrostatic pressure wherever water has come in contact with the petroleum.

(*c*) Associated porous beds occupying such a position relative to the source of the oil and to impervious barriers as to permit of the petroleum passing from the source into the final reservoir and being there confined by impervious strata. Wet shale or clay and certain fine-grained water-impregnated sands are believed to be among the effective barriers to the migration of the oil.

(*d*) Occurrence of the accumulations at a depth far enough below the surface and distant enough from outcrops to preclude the escape of the lighter hydrocarbons, and still at depths which may be profitably reached by the drill. The areas within the lines shown on the map (Pl. II) as bounding the possibly productive territory are those in which the top of the supposed oil zone has been calculated as possibly within a vertical distance of 4,500 feet from the surface. A depth of 4,500 feet below the surface has been arbitrarily taken as the maximum to which it is possible to drill by present methods in the region under discussion, as this is about the maximum depth of holes in California which have been drilled with a standard rig. It may be possible to go deeper than this, but for the present this limit seems sufficiently great. Whether or not a well can be profitably drilled depends upon so many factors, such as quantity of oil produced compared with cost of drilling, price of oil, etc., that local conditions must determine the result in each specific case.

It seems very unlikely that oil, even in small amounts, will be found in any of the rocks underlying the Tejon (Eocene)—that is, in the Cretaceous or Franciscan formations (see map, Pl. I)—while it is quite likely that it will be found in the Tejon and in the formations immediately overlying the latter, whether or not in paying quantities depending on the factors above enumerated. In the following paragraphs it is the intention of the writers to give their personal opinion as to the probabilities of the occurrence of petroleum in regions not yet thoroughly tested by the drill. It must be borne in mind, however, that absolute determination, by work on the surface, of the occurrence or nonoccurrence of oil in any one locality is not possible. The best that can be done is to calculate the degree of probability on the basis of surface indications and structural conditions.

AREAS DISCUSSED.

The areas for which the probabilities of the occurrence of petroleum is discussed in the following paragraphs are as follows: Northwest of Eastside field, Eastside field, Anticline Ridge and Guijarral Hills, Westside field, south of Waltham Creek on Jacalitos anticline, Reef Ridge south to Dagany Gap, and Kettleman Hills.

NORTHWEST OF EASTSIDE FIELD.

The well of T. C. Oil Company in sec. 2, T. 19 S., R. 15 E., has proved the eastern flank of the Coalinga anticline as far north as the northern edge of the area shown on the map (Pl. I). Near this point the beds bend from a strike of almost due north to one of N. 30° or 40° W., the dip at the same time steepening to 30° or more in secs. 34 and 35, T. 18 S., R. 15 E. The writers have examined the country only as far north as the middle of sec. 29, T. 18 S., R. 15 E., but up to this point the shales of the Tejon (Eocene) were found well developed, and it is therefore believed that the overlying Miocene sands will be found productive as in the region farther south. The steepening of the dip of the beds in this undeveloped territory will necessarily narrow the productive ground materially, decreasing it to a band less than 2 miles wide, whereas southward in the middle of the Eastside field, where the dip is approximately only 16°, the width of the productive belt is over 3 miles. Toward the northern end of the Eastside field as mapped in this report, and still farther northwest, only zone D, the lower part of the Vaqueros (lower Miocene), it is believed, will be found productive, and here not as prolifically as farther south, owing to the thinning of the productive zone.

EASTSIDE FIELD.

Little need be said concerning the probable development in the already well-proved areas of the Eastside field, as their future may be inferred from a perusal of the paragraphs devoted to the discussion of the geology of their wells. It should be borne in mind, however, that the lower part (and what in sec. 28 and the western part of secs. 22 and 27 is the richest part) of the oil measures has not been tested in those wells farthest down the dip and should yield good returns for the extra cost of deepening if water is not encountered at the greater depth; and there is no evidence at present indicating that water exists at the base of the oil in this area. It is believed that oil in commercial quantities will never be found above the "Big Blue" in the Eastside field (a possible exception to this may be the "St. Paul sand" in sec. 34), so that wells put down outside of the limit of those in which the bottom of the "Big Blue" is penetrated at less than 4,500 feet will probably never pay.

Two factors militate against the successful exploitation of the southwestern flank of the Coalinga anticline immediately southwest of the developed Eastside territory. These are (*a*) the steep dip (almost perpendicular in places) of the beds, which carries the oil zone rapidly downward to great depths toward the southwest, and (*b*) the more locally disturbed condition of the various beds throughout this zone of steep dip. It is believed that at least the lower part of the oil zone along this flank will be found more or less productive wherever it can be reached, but it is also believed, and this belief is strengthened by the experience of those who have drilled in the territory, that the disturbed conditions of the beds will make the shutting off of the water difficult or sometimes impossible, thus hindering the most successful manipulation of the wells. Toward the southeastward the dips lessen in degree and the resulting conditions are somewhat more favorable for successful wells.

Within the area of the shale and interbedded sandstone of the Tejon (Eocene) lying between the Cretaceous (Chico) beds on the west and the overlying Vaqueros (lower Miocene) sandstone on the east and extending from Oil City northward beyond secs. 29 and 30, T. 18 S., R. 15 E., it is believed that favorable locations for productive wells yet remain undeveloped. Surface indications lead to the belief that wherever in this area the sands interbedded with the shale of the Tejon formation are of a porous character they contain appreciable and in some cases probably commercial quantities of petroleum at available depths. As the quality of the oil obtained from the Tejon sands is usually considerably higher than that found in the Miocene, small producers in the Tejon area should pay where the same production would involve a loss elsewhere. It is believed that a well site so chosen that the prospective sand would be encountered at 600 feet or more below the surface would be the most favorable for exploiting the Tejon territory. The same conclusions as those just expressed have been reached for practically the whole band of Tejon extending intermittently along the western edge of the Miocene in the Coalinga district from sec. 29, T. 18 S., R. 15 E., to Little Tar Canyon, northeast of Dudley. Furthermore, it is believed that productive sands in the Tejon may be tapped by wells which start in overlying formations, but predictions as to favorable locations for such tests would be unreliable owing to the unconformable relation of the overlying beds to the Tejon.

ANTICLINE RIDGE AND GUIJARRAL HILLS.

Throughout its entire length along the southwestern edge of the developed territory in the Eastside field the axis of the Coalinga anticline dips southeast at about 9° until in the northwestern part of sec. 2, T. 20 S., R. 15 E., it assumes an angle of approximately 4°. The territory along this comparatively low-dipping portion of the anticline has been proved productive as far southeastward as the middle of the NW. ¼ sec. 2, T. 20 S., R. 15 E. Southeastward from this last-mentioned locality the indications for productive wells are good. The productive territory will be limited to that portion of the anticline where the productive sands lie at such a depth as to be profitably reached by the drill.

In drawing conclusions as to just how far southeastward along the axis of the anticline this limit will be two factors have to be taken into consideration: (*a*) Dip or pitch of the anticline, and (*b*) thickening of the formations toward the southeast.

Regarding the first factor (*a*) surface evidence indicates a dip of about 4°, or something like 350 feet to the mile. Certain evidence offered by the well logs of the territory in question, however, indicate a much lower dip, about 2°, or 185 feet to the mile.

Regarding the second factor (*b*) a conservative estimate indicates that at its nearest point to the surface in the northern portion of the Kettleman Hills the top of the oil-bearing zone may lie within 3,500 feet of the surface. This depth assumes a very considerable increase in the thickness of the formations above the oil-bearing Vaqueros over the thickness of the same formations in the Eastside field. Just where this thickening of the beds begins it is not possible to find out, but it is believed to commence toward the lower end of Anticline Ridge; that is, along the Coalinga anticline a little way north of the railroad. Taking all of the evidence into consideration, it seems probable that the conditions indicated by the contours on the map (Pl. II), a dip of 4°, or 350 feet to the mile, along the anticline, will be found to be the average as far southeastward as the Guijarral Hills, although it may possibly be less in secs. 2 and 12, T. 20 S., R. 15 E., and possibly somewhat more in the region of the Guijarral Hills. Owing to the much steeper dip on the southwestern flank of the anticline than on the northeastern, the productive ground will be found to extend much farther away from the axis on the latter flank than on the former. as indicated by the contour map.

WESTSIDE FIELD.

Owing to the rapid thinning and even entire pinching out of the Vaqueros or lower Miocene oil-bearing formation toward the western edge of the Westside field, predictions as to the exact depths at which the top of this formation will be encountered at any particular point are unusually hazardous. For this reason the top of the lowest of the Jacalitos (upper Miocene) petroliferous zones (zone B) was chosen for contouring, as this latter extends over the whole region, although both at the northern and the southern ends of the field it is not commercially productive. There are no known reasons at present for believing that any of the territory in the main portion of the Westside field under which the productive measures lie at a greater depth than 500 feet are unproductive. Local conditions, such as the extreme thinness of the shale or clay separating water from oil sands, may make the manipulation of certain wells more or less difficult or possibly unsuccessful, but there is no evidence of "bottom" or "edge" water in any of the wells so far drilled that condemns any of the territory generally considered as proved. On the contrary, evidence is available indicating that in many of the wells which have penetrated but a short distance into the oil-bearing zone there are underlying and untouched sands even more productive than those already developed. It is the belief of the writers that in this field, as in the Eastside, the sands become more productive the nearer they lie to the brown shale of the Tejon. It seems worth while, therefore, in those areas where conditions are such that water could be plugged off if encountered below the already tested productive sands, to deepen to the beds immediately overlying the brown shale. Such a procedure, however, will require great care in avoiding the flooding of the upper productive beds if water should happen to be encountered in the oil-bearing series of beds.

It is believed that considerable commercially productive territory is yet untested in the southwestern portion of the Westside field, especially north and northeast of the fault (see Pl. II) which extends east and west through the middle of the SW. ¼ sec. 12, T. 21 S., R. 14 E. The extent of this productive area is believed to depend on whether the various Miocene sands are underlain by the Tejon (Eocene) formation or by Knoxville-Chico (Cretaceous) rocks. In the former case it is believed that the beds will be found commercially productive; in the latter case, except within half a mile or so of the contact between the Tejon and the Knoxville-Chico, it is believed the oil sands will be dry or only poorly saturated. Direct evidence of the trend of the contact between the Knoxville-Chico and Tejon ceases in the southwest corner of sec. 26, T. 20 S., R. 14 E., because south of there it is entirely covered by the later formations. At this locality its direction is about S. 25° E., but this strike is believed to swing eastward so that the contact passes north of the corner of secs. 1, 12, 6, and 7. The partial failure of the well in the SE. ¼ sec. 12 is believed to be due entirely to local conditions accompanying the fault to the north of the well, while the water in the well in the SE. ¼ sec. 12 comes from beds believed to be Knoxville-Chico.

JACALITOS ANTICLINE.

The first locality south of the southwest corner of sec. 26, T. 20 S., R. 14 E., where the Tejon (Eocene) formation is definitely known, is in Sulphur Spring Canyon in the southern part of sec. 23, T. 22 S., R. 15 E. As mentioned above, there is evidence that the contact between the Knoxville-Chico and the Tejon passes north of the corner of secs. 1 and 12, T. 21 S., R. 14 E., and secs. 6 and 7, T. 21 S., R. 15 E. Just how this contact trends between this corner and the Sulphur Spring Canyon locality is not definitely known, but it is the belief of the writers after a study of the intervening region that the contact soon bends to the south after passing into the northern part of sec. 7, T. 21 S., R. 15 E., then swings around to a southwesterly trend, continuing this down to Sulphur Spring Canyon, in a somewhat similar way to that followed by the later beds, now exposed over the area. The relation of the whereabouts of this contact between the Knoxville-Chico and Tejon to the future development of the region is obvious when it is remembered that only those portions of the Miocene sands which overlie the Tejon (Eocene) are believed to be productive. It is the opinion of the writers, therefore, that the basal Miocene sands are likely to be commercially oil bearing only in the area northeast of a line which passes in a general way southwesterly from the eastern part of sec. 7, T. 21 S., R. 15 E., to sec. 23, T. 22 S., R. 15 E. Passing southward from the region immediately north of Alcalde Canyon the formations which overlie the oil-bearing Vaqueros thicken rapidly until in the region of Jacalitos Creek, the Jacalitos formation (upper Miocene) alone is 3,500 feet through, whereas in the Alcalde Canyon region it is less than 1,500 feet. This great thickening of the beds above the oil zone toward the south will necessitate much deeper wells than would be required if the formations were uniform. At the axis of the Jacalitos anticline on Jacalitos Creek, where the supposedly productive zone approaches nearest to the surface, it is estimated that the top of the Vaqueros is about 3,600 feet below the surface. As the axis plunges northward north of the creek and southward along the anticline from the high hill immediately south of the creek it is obvious that the territory possible of development is very limited. The northeastern flank of the Jacalitos anticline dips much more steeply than the southwestern flank, so that the band of productive ground on the northeast will be much narrower than that on the southwest. Owing to the uncertainties incident to the complicated structure at the northern end of the Jacalitos anticline in sec. 18, T. 21 S., R. 15 E., and the rapid rate of thickening of the beds, quantitative statements concerning the depth of the oil zone below the surface at any one point will not be attempted for the region south of Alcalde Canyon. A suggestion as to the probable depth at which the oil zone lies may be gathered from the statement that it is struck at about 700 feet below sea level (1,600 feet below the surface in the NW. ¼ sec. 18, T. 21 S., R. 15 E.) and as before stated is probably some 2,800 feet below sea level (3,600 below the surface) on the axis of the anticline on Jacalitos Creek. This great increase in depth occurs even in the face of the fact that the axis of the anticline is plunging (near its northwestern end as much as 15°) toward the northwest.

REEF RIDGE SOUTH TO DAGANY GAP.

The great monocline of Tertiary beds which flanks Reef Ridge on the east and forms the Kreyenhagen Hills is underlain by the Tejon formation from a point at least as far north as Sulphur Spring Canyon (in sec. 23, T. 22 S., R. 15 E.) to the head of Little Tar Canyon (in sec. 35, T. 23 S., R. 17 E.). Throughout nearly the whole extent of this Tejon band it shows unmistakable signs of its petroleum contents. Many oil seepages also occur from the Vaqueros sands overlying the Eocene, so that there is no doubt as to the presence of petroleum throughout practically the whole length of the region under discussion. Furthermore, productive wells on Canoas Creek, in Big Tar Canyon, and elsewhere (see pp. 108–111) have proved the presence of oil in commercial quantities in at least certain localities. Although the territory offers no promise of a large individual production, it is the belief of the writers that productive wells may be put down along practically the whole strip of territory from between Jacalitos and Canoas creeks to Little Tar Canyon. West of Jacalitos Creek the Tejon is apparently lacking or else is thin and insignificant; southeast of the head of Little Tar Canyon the Tejon is cut off by the Castle Mountain fault. It is therefore not likely that the productive sands extend far either northwest of Sulphur Spring Canyon or southeast of the head of Little Tar Canyon. Indications of petroleum are in evidence in the axis of the Pyramid Hills anticline, southeast of Dudley, and still farther southeastward toward the Devil's Den country, so that the extension of the productive belt in a southeasterly direction from Little Tar Canyon is probably only locally affected by the fault. The lighter oil is to be expected in the Tejon as in the Coalinga field, but the best production will doubtless be found in the Vaqueros or lower Miocene sand. The production in either case will probably not be large, for the steep dip of the beds precludes the conditions necessary for great accumulations of oil. The steep dip, however, so increases the distance through which the wells may penetrate the sand that the lack of complete saturation may be partly compensated for by increased surface of sand exposed in the well. An item that should not be overlooked in drawing conclusions concerning this strip of territory is the probable occurrence of water in or closely associated with the oil sands. Nearly all of the oil seepages in the region are accompanied by water, and many of the test wells have been abandoned on account of it, so that trouble from this source should not cause surprise to those who may undertake to exploit the region. The depth to which the oil sands along Reef Ridge may be exploited is limited by the relation between the cost of drilling plus operation and the production and value of the oil; and by whether or not the water that is apparently associated with the oil-bearing beds is "bottom" or "edge" water. These factors are determinable only by actual test. The area outlined on the map (Pl. I) as probably productive embraces all of the territory along Reef Ridge in which it is thought that the top of the Vaqueros or lower Miocene sands will be encountered at a depth less than 4,500 feet below the surface. At some localities seepages indicate that the productive zone is near the base of the formation; at other localities the evidence favors the theory that the top will be found the most productive. All of the evidence seen by the writers leads to the conclusion that productive bodies of petroleum will not be encountered in or above shale of the Santa Margarita formation, that is, above the top of the Vaqueros (lower Miocene) zone.

KETTLEMAN HILLS.

The Kettleman Hills were formed by an uplift of the sedimentary formations of this region along the Coalinga anticline. It is an interesting and important problem to consider whether this great arch, the summit of which has subsequently been in large part worn away by erosion, has brought within reach of the surface the beds which are oil-bearing a few miles away. The conditions for the accumulation and preservation of oil in this broad, regular fold would appear to be good, and the question as to the occurrence of valuable deposits resolves itself principally into two problems; (1) whether the hills are underlain by the Tejon, the original oil-bearing formation in this district, and whether oil is therefore most probably present; and (2) whether the oil-bearing beds are brought sufficiently near to the surface by the anticline to be accessible. There is no direct evidence obtainable on either of these questions owing to the complete hiding of the oil-bearing formations, if such there be, by the great thickness of overlying formations; and there will be no such evidence until a test is made by means of the drill, but the geologic facts observed in the hills and in other parts of the district afford indirect evidence of considerable importance favoring the theory that the necessary conditions mentioned above do exist.

As regards the first condition, it may be reasonably supposed that the Tejon formation underlies the whole of the foothill and valley region within at least a few miles east and southeast of its outcrop in the hills around Pleasant Valley and along Reef Ridge. There is no known reason for supposing otherwise. The San Joaquin Valley has been during long periods of geologic time a basin of depression in which deposition of sediments and subsidence have gone on, and there is evidence to show that during the Eocene, when the Tejon formation was being deposited in the sea that covered part of the area under discussion, the present Diablo Range was, at least in part, a belt of land that stood out with considerable relief and formed the shore line. The sea extended thence eastward, and unless a belt of land rose where the present Kettleman Hills stand the formation must have been deposited over their area. It is possible that the Coalinga anticline is an old axis of uplift that may have determined an area of relief in previous epochs, but it is not probable. The fact that the Cretaceous beds on Joaquin Ridge are not more disturbed than the younger ones lapping over the anticline farther east indicates that no great uplift occurred along this anticline before the latest period of movements, during which all of the formations were affected at the same time.

The same reasoning applies to the question whether the Tejon formation when once deposited over the area now occupied by the Kettleman Hills was worn away by erosion before the deposition of the younger Tertiary formations and the preservation in them of the petroleum. If no uplift of magnitude occurred, it is not likely that the formation was worn away. In fact, it was probably less eroded than in the region farther west, where it is now exposed, a region that was nearer the shore line and more subjected to disturbances. It may therefore be assumed as a good working hypothesis that the Tejon was originally deposited and still exists beneath the formations covering the surface of the Kettleman Hills. Similarly it is to be supposed that the whole succession of Tertiary formations is the same beneath these hills as in other parts of the district. Whether or not the Tejon is oil-bearing can not be told, but being so near to the extensive area in which it is petroliferous the chances are good that it is likewise so beneath these hills.

As regards the second condition, the evidence afforded by the thickness of the formations in various parts of the district must be brought to bear in order to determine at what depth the oil-bearing beds will be met. The anticline exposes along its axis a low portion of the Etchegoin (uppermost Miocene) formation, and therefore the drill will have to pierce the base of this formation and the whole of the Jacalitos (early upper Miocene) and Santa Margarita (upper middle Miocene) formations in order to reach the petroliferous beds of the Vaqueros (lower Miocene), provided that these formations are present as they have been assumed to be. The formations here probably bear a closer similarity in occurrence and thickness to the same formations on the western side of the syncline along the Kettleman Plain than they do to the formations in the Coalinga field. The oil probably collects, as it does along Reef Ridge, in the Vaqueros sandstone overlying the Tejon (Eocene) and is retarded from further upward migration by the compact shales of the Santa Margarita.

The question of the thickness of the formations may be taken up with relation to each one separately, beginning with the exposed Etchegoin. This formation has a thickness of approximately 3,500 feet throughout the Kreyenhagen Hills, of which about 2,700 is below and 800 above the upper *Mulinia* zone. On Anticline Ridge the formation has a thickness, only roughly measurable, of about 1,700 feet. In the Kettleman Hills, inasmuch as the base is not certainly exposed, the whole formation can not be measured. The maximum thickness exposed is about 3,000 feet in the south-central part of the hills along that part of the anticline where it plunges in both directions. Fossil beds are there exposed which may be close to the base of the formation. If they are, the whole formation is thinner than in the Kreyenhagen Hills. In other parts of the Kettleman Hills, where the lowest beds exposed are considerably above the base, the only means of determining the comparative thickness of the formation here and elsewhere is to compare the thickness from the summit down to the upper *Mulinia* zone, which has been correlated with a similar zone in the Kreyenhagen Hills. This thickness is about 1,900 to 2,000 feet in the northern part of the Kettleman Hills, but increases to 2,300 or 2,400, if not more, in the southern half, on the southwest flank of the anticline. Here again, therefore, there is indicated a thinning of the formation in the Kettleman Hills, as compared with the Kreyenhagen Hills, and this gradual decrease appears to continue on the northeastern side of the Kettleman Hills. On the other hand, there is a very decided thickening southeastward from Anticline Ridge along the anticline. In conclusion, all that may be said is that the Etchegoin is at least 2,000 feet and probably more nearly 2,500 feet thick in the northern part of the Kettleman Hills and at least 3,000 feet thick in the southern part. The thickness of it that must be pierced along the axis of the anticline in order to reach the underlying Jacalitos decreases gradually southward toward the central portion of the hills. At the south side of sec. 34, T. 21 S., R. 17 E., the upper *Mulinia* zone arches over the anticline and plunges northwestward beneath higher beds. At this point the beds are practically horizontal on the very axis of the fold and the depth to the top of the Jacalitos is probably only a few hundred feet, possibly in the neighborhood of 500 feet. From there southeastward to sec. 1, T. 23 S., R. 18 E., the thickening of the formation is more than offset by the plunge of the anticline in the opposite direction, and the depth to the Jacalitos gradually decreases. Thence southward the depth is probably nowhere more than a few hundred feet and is in general less than in the northern part of the hills.

The Jacalitos formation has a thickness similar to that of the Etchegoin both in the Kreyenhagen Hills and the Coalinga field. The question of the accessibility of the oil sand in the Kettleman Hills hinges in large measure on the question whether this similarity in thickness between the two formations holds good there. Does the Jacalitos become thinner eastward from the Kreyenhagen Hills, as the Etchegoin seems to do? It is very probable that it does.

The Santa Margarita increases in thickness from Zapato Creek to Dagany Gap from about 200 feet to over 1,000 feet. It probably underlies the Kettleman Hills with some such thickness and with a probable similar thickening southward. There is no way of telling whether it thickens or thins eastward from the Kreyenhagen Hills, and it may therefore be assumed as constant.

On the basis of the probable conditions outlined above the combined thickness of the lower part of the Etchegoin below the upper *Mulinia* zone and of the Jacalitos and Santa Margarita formations may be arbitrarily assumed to be 3,500 feet in the northern part of the Kettleman Hills and 4,500 in the south-central part. The lines on the map over the Kettleman Hills showing the possible limits of the productive territory are drawn on the basis of such an assumption.

These figures are moderate estimates and the chances are small that the thicknesses are less than this. It must be borne in mind, however, that they are at best only guesses based on a balance of probabilities. If these figures be true it means that the top of the Vaqueros formation, the supposed oil sand, lies between 3,500 and 4,000 feet immediately below the axis of the anticline throughout the hills southeast of the Big Tar Canyon-Lemoore road. Away from the axis on either side the beds begin to dip away and the depth to the Vaqueros increases rapidly. The lines bounding the supposed oil territory represent the limits of the area in which the top of the Vaqueros would be reached within 4,500 feet vertically down if the above-assumed thicknesses were correct. On the other hand, if the formations are as thick as they are in the Kreyenhagen Hills, the top of the Vaqueros would be considerably below 4,500 feet even along the axis of the anticline. In the southern part of the Kettleman Hills, for a few miles north of Avenal Gap and in the group south of there, the structure is poorly displayed. Little definite information has been obtained further than that the horizon exposed along the axis is in the lower portion of the Etchegoin. Owing to the removal of the Eocene by faulting near Little Tar Canyon and south of there it is possible that the Tejon is not present beneath the southern portion of the Kettleman Hills.

No surface indications of oil are known to exist in the Kettleman Hills, but it is not likely that oil would have been allowed to escape through the great thickness of overlying beds forming the regularly arching anticline. It is supposed, also, that the oil is retained by the overarching shale of the Santa Margarita. Indications suggesting petroleum have been observed in the Lost Hills several miles south of the south end of the Kettleman Hills. The Lost Hills may be due to an extension of the Coalinga anticline southward, and it is possible that the fold plunges northward and exposes a low portion of the series into which the oil has had access.

In conclusion, it may be said that the Kettleman Hills offer a fair chance for the discovery of oil at a depth of from 3,000 to 4,500 feet along the axis of the anticline, and that the conditions favor a well-preserved supply. The only possible means of gaining any definite knowledge of the oil-bearing formations beneath these hills is by drilling. In order to test the possibilities of the region satisfactorily wells should be sunk immediately on the axis of the anticline. The most favorable location for a test well would probably be between the Big Tar Canyon-Lemoore road and a point 13 miles southeast of the northwest end of the hills.

PRODUCTION.

The following table of production of the Coalinga district by calendar years from 1897 to 1907 was compiled by Miss Belle Hill, under the direction of Dr. David T. Day, of the Geological Survey. The production for 1908 will probably be about 12,000,000 barrels, which, with the greatly increased price (63 to 75 cents per barrel), will bring the value of the product for the year close to $8,000,000.

Production of Coalinga district, 1897 to 1907.

[In barrels of 42 gallons each.]

Year.	Production.	Value.	Year.	Production.	Value.
1897	70,140		1903	2,138,058	$705,559
1898	154,000		1904	5,114,958	1,520,847
1899	439,372		1905	10,967,015	2,657,009
1900	532,000	$532,000	1906	7,991,039	1,848,300
1901	780,650	390,325	1907	8,871,723	3,091,934
1902	572,498	257,629			

By a rough estimate based on the data in the hands of the writers, the amount of available oil contained before exploitation began in that part of the Coalinga district shown on the contour map (Pl. II) was 2,875,000,000 barrels of 42 gallons each. Of this amount about 2,000,000,000 barrels was contained in the territory west of the Coalinga syncline and 875,000,000 barrels east of the syncline. The total amount taken from the ground up to the present time, including an estimated production of 12,000,000 barrels for 1908, approaches 50,000,000 barrels, which, when subtracted from the estimated total, leaves 2,825,000,000 barrels available after 1908. At the present rate of production this supply would last over 200 years, but with the rapid rate at which the increase in production is now taking place the time during which the supply will hold out promises to be far less. Moreover, it is not possible to state what percentage of the oil present can ultimately be obtained.

The estimate is, of course, merely an approximation. It was arrived at by assuming a 10 per cent impregnation of the oil sands and calculating from all the data available the probable thickness of sand under each quarter section.

TRANSPORTATION FACILITIES.

One railroad and two pipe lines comprise the transportation facilities for the oil produced in the Coalinga district.

A branch of the Southern Pacific Railroad joins Coalinga with the main lines at Hanford and Goshen Junction, and also with the main lines of the Atchison, Topeka and Santa Fe Railway at Hanford and Visalia. The storage tanks and loading racks for the district are at Ora station, 1½ miles northeast of Coalinga.

A 6-inch pipe line of the Coalinga Oil Transportation Company, a subsidiary of the Associated Oil Company, joins Coalinga with the seaboard at Monterey, 110 miles northwest. This line was first constructed in 1904 as an independent project, and was generally known, from the name of its projector, as the Matson pipe line. The route traversed is along Alcalde Canyon, Waltham Valley, Priest Valley, Lewis Creek, and the Salinas Valley. Several pumping stations are situated along the line between Coalinga and Monterey, the main pumping station being located in the SW. ¼ sec. 18, T. 20 S., R. 15 E.; it is joined by minor lines with various parts of the Eastside and Westside fields.

An 8-inch branch pipe line, 28 miles long, joins the Coalinga field with the main Kern River-Point Richmond line of the Standard Oil Company at Mendota. The total distance from Coalinga to tidewater by this line is 198 miles. The main pumping station of this company for the Coalinga field is in the NW. ¼ sec. 36, T. 19 S., R. 15 E.

Numerous local lines transport the oil from various parts of the field to the shipping stations. Among these lines are those of the Union Oil Company from sec. 13, T. 20 S., R. 14 E., to Ora; the California Oilfields, Ltd., from the Eastside field to Ora; the Coalinga Oil Company, from the Oil City field to Ora; Westside line, from the Westside field to Ora, and the Associated Oil Company, from the Westside field to Ora.

MINERAL LANDS.

The following areas within the Coalinga district have been classified as mineral lands, and such of these as yet belong to the Government have been withdrawn from any but mineral-land entry. The lands classified as mineral include all those lying between the outcrop of the lowest oil-bearing formations, the Tejon (Eocene), and a line marking the limits of the area in which the uppermost productive oil zone (zone B), can be reached by a well less than 4,500 feet in depth. (See pp. 113–114 for relative probability of productiveness of these lands.)

List of mineral lands in Coalinga district.

T. 18 S., R. 15 E.:
  W. ½ and SE. ¼ sec. 36, secs. 35, 34, and 33.

T. 19 S., R. 14 E.:
  S. ½ and NE. ¼ sec. 25, S. ½ sec. 35, and sec. 36.

T. 19 S., R. 15 E.:
  Secs. 1 to 4, 8 to 17, SE. ¼ sec. 18, and secs. 19 to 36 except NW. ¼ sec. 19.

T. 19 S., R. 16 E.:
  W. ½ secs. 7, 18, 19, and 30, and all of sec. 31.

T. 20 S., R. 14 E.:
  Secs. 1 to 3, 10 to 15, 22 to 26, 35, and 36.

T. 20 S., R. 15 E.:
  All of township except secs. 23, 26, 35, 36, SW. ¼ sec. 14, E. ½ sec. 27, N. ½ and NE. ¼ sec. 25.

T. 20 S., R. 16 E.:
  W. ½ sec. 5, secs. 6, 7, 8, SW. ¼ sec. 9, secs. 16 to 21, W. ½ sec. 22, secs. 27 to 30, NE. ¼ sec. 31, secs. 32 to 33, and W. ½ sec. 34.

T. 21 S., R. 14 E.:

Sec. 1, E. ½ sec. 2, sec. 12, N. ½ and SE. ¼ sec. 13.

T. 21 S., R. 15 E.:

Secs. 2 to 9, N. ½ sec. 10, NW. ¼ sec. 11, S. ½ sec. 16, secs. 17, 18, 21, 22, NW. ¼ and S. ½ sec. 23, secs. 26, 27, E. ½ sec. 28, N. ½ and SE. ¼ sec. 34, and W. ½ sec. 35.

T. 21 S., R. 16 E.:

N. ½ sec. 3 and NE. ¼ sec. 4.

T. 21 S., R. 17 E.:

Secs. 33, 34, and NW. ¼ and S. ½ sec. 35.

T. 22 S., R. 15 E.:

SW. ¼ sec. 5, S. ½ sec. 6, secs. 7, 8, NW. ¼ and S. ½ sec. 9, SW. ¼ sec. 10, SW. ¼ sec. 13, NW. ¼ and S. ½ sec. 14, secs. 15, 16, N. ½ sec. 17, N. ½ sec. 18, NW. ¼ sec. 22, NW. ¼ and E. ½ sec. 23, secs. 24, 25, and NE. ¼ sec. 26.

T. 22 S., R. 16 E.:

NW. ¼ and S. ½ sec. 19, SW. ¼ sec. 20, SW. ¼ sec. 27, NW. ¼ and S. ½ sec. 28, secs. 29, 30, N. ½ sec. 31, secs. 32 to 34, and SW. ¼ sec. 35.

T. 22 S., R. 17 E.:

NW. ¼ and S. ½ sec. 1, secs. 2, 3, E. ½ sec. 4, NW. ¼ and E. ½ sec. 10, secs. 11, 12, NW. ¼ and E. ½ sec. 13, and NE. ¼ sec. 14.

T. 22 S., R. 18 E.:

Sec. 7, NW. ¼ and S. ½ sec. 8, NW. ¼ and S. ½ sec. 16, secs. 17, 18, N. ½ sec. 19, secs. 20, 21, 22, SW. ¼ sec. 25, secs. 26, 27, 28, NE. ¼ sec. 29, NE. ¼ sec. 33, and secs. 34, 35, and 36.

T. 23 S., R. 16 E.:

S. ½ sec. 1, secs. 2, 3, 4, N. ½ sec. 10, secs. 11, 12, and N. ½ sec. 13.

T. 23 S., R. 17 E.:

Sec. 7, S. ½ sec. 8, SW. ¼ sec. 15, NW. ¼ and S. ½ sec. 16, sec. 17, NW. ¼ and E. ½ sec. 18, N. ½ sec. 20, secs. 21, 22, SW. ¼ sec. 23, SW. ¼ sec. 25, sec. 26, N. ½ and SE. ¼ sec. 27, NE. ¼ sec. 35, and sec. 36.

T. 23 S., R. 18 E.:

Secs. 1, 2, NE. ¼ sec. 3, E. ½ sec. 11, secs. 12, 13, N. ½ and SE. ¼ sec. 24, NE. ¼ sec. 25, and SW. ¼ sec. 31.

T. 23 S., R. 19 E.:

W. ½ sec. 6, secs. 7, 18, 19, W. ½ sec. 20, SW. ¼ sec. 28, secs. 29, 30, E. ½ sec. 31, secs. 32, 33, and SW. ¼ sec. 34.

T. 24 S., R. 18 E.:

SW. ¼ sec. 5, secs. 6, 7, NW. ¼ and S. ½ sec. 9, SW. ¼ sec. 15, sec. 16, N. ½ and SE. ¼ sec. 17, N. ½ and SE. ¼ sec. 21, NW. ¼ and S. ½ sec. 22, sec. 27, E. ½ sec. 28, sec. 34, and W. ½ sec. 35.

T. 24 S., R. 19 E.:

Secs. 3, 4, N. ½ and SE. ¼ sec. 5, secs. 9, 10, 15, 16, 21, 22, SW. ¼ sec. 26, secs. 27, 28, N. ½ and SE. ¼ sec. 33, sec. 34, and NW. ¼ and S. ½ sec. 35.

OIL COMPANIES AND OIL WELLS IN THE COALINGA DISTRICT.

The following is a practically complete list of all of the oil companies which have drilled or are drilling wells in the Coalinga district. The locations of the wells are indicated wherever known and the elevation of each well given in most instances, having been obtained by instrument survey by E. P. Davis, topographer. There are now 395 productive wells, 75 abandoned wells, and between 75 and 100 drilling wells in the district.

Oil companies and oil wells in Coalinga district.

[Location by Mount Diablo base and meridian.]

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
Ætna. (See California Oilfields, Ltd.)				*Feet.*
Ajax		[a] 1	SW. ¼ sec. 32, T. 19 S., R. 15 E.	
American Petroleum		[b] 2	Sec. 30, T. 20 S., R. 15 E.	
Angelus		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	840
Do		2	do	842
Arline. (See California Oilfields, Ltd.)				
Associated		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,255
Do		2	do	1,235
Do		3	do	1,223
Do		4	do	1,208
Do		5	do	1,144
Do	Sauer Dough No. 1	1	do	1,435
Do	Sauer Dough No. 2	2	do	1,304
Do	Sauer Dough No. 3	3	do	1,313
Do	Sauer Dough No. 4	4	do	1,388
Do	Sauer Dough No. 5	5	do	1,435
Do	Sauer Dough No. 6	6	do	1,283
Do	Sauer Dough No. 7	7	do	1,340
Do		1	SE. ¼ sec. 36, T. 20 S., R. 14 E.	835
Do		2	do	875
Do		3	do	831
Do		4	do	934
Do		5	do	828
Do		21	NE. ¼ sec. 36, T. 20 S., R. 14 E.	800
Do		23	do	814
Do		25	do	828
Do		27	NW. ¼ sec. 36, T. 20 S., R. 14 E.	843
Do		29	do	858
Avenal Land and Oil		[a] 2	Sec. 18, T. 23 S., R. 17 E.	
Avon. (See California Oilfields, Ltd.)				
B and B	Brix and Buntin	1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	848
Do		2	do	852
Baby King		[a] 1	NE. ¼ sec. 11, T. 23 S., R. 16 E.	
Badger State		[a] 1	Sec. 1, T. 21 S., R. 14 E.	
Black Mountain		[a] 2	NW. ¼ sec. 33, T. 22 S., R. 16 E.	
Blair		[b] 1	NW. ¼ sec. 14, T. 21 S., R. 15 E.	
Blue Diamond		[a] 1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	920
Blue Goose		[a] 1	NE. ¼ sec. 20, T. 19 S., R. 15 E.	
Bonanza King		[a] 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Boston and California		[b] 1	SE. ¼ sec. 24, T. 19 S., R. 15 E.	
Buena Vista (Kettleman Hills).				
Buntin. (See California Diamond.)				
Caledonian		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	882
Do		[a] 2	do	880
Do		3	do	847
Do		4	do	842
California and New York		1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	834
Do		2	do	848
Do		3	do	829
Do		4	do	835
Do		5	do	843
California Diamond		1	SW. ¼ sec. 12, T. 19 S., R. 15 E.	802
Do	Ellis, No. 1	3	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,192
Do		4	do	1,196
Do	Buntin, No 1	[a] 1	NW. ¼ sec. 24, T. 21 S., R. 15 E.	
California Monarch		1	SE. ¼ sec. 26, T. 19 S., R. 15 E.	954
Do		[b] 2	do	889
California Oil and Gas		[a] 1	SE. ¼ sec. 19, T. 19 S., R. 15 E.	
California Oilfields, Ltd	Avon, No. 1	1	SW. ¼ sec. 14, T. 19 S., R. 15 E.	1,101
Do	Avon, No. 2	2	NW. ¼ sec. 14, T. 19 S., R. 15 E.	1,035
Do	Kaweah, No. 1	3	NE. ¼ sec. 14, T. 19 S., R. 15 E.	877
Do	Kaweah, No. 2	4	SE. ¼ sec. 14, T. 19 S., R. 15 E.	950
Do	Avon, No. 3	[b] 5	NW. ¼ sec. 14, T. 19 S., R. 15 E.	856
Do		1	SE. ¼ sec. 21, T. 19 S., R. 15 E.	1,451
Do		2	do	1,322
Do		3	do	1,444
Do		4	do	1,340

[a] Abandoned. [b] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
California Oilfields, Ltd		5	SE. ¼ sec. 21, T. 19 S., R. 15 E.	1,429
Do		6	do	1,461
Do		7	do	1,377
Do		8	do	1,383
Do		9	NE. ¼ sec. 21, T. 19 S., R. 15 E.	1,368
Do	Arline, No. 1	1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	1,007
Do	Arline, No. 2	2	NW. ¼ sec. 26, T. 19 S., R. 15 E.	1,028
Do	Northeastern, No. 1	3	NE. ¼ sec. 26, T. 19 S., R. 15 E.	950
Do		1	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,387
Do		2	do	1,363
Do		3	do	1,349
Do		4	do	1,353
Do		5	do	1,380
Do		6	do	1,214
Do		7	do	1,331
Do		8	do	1,305
Do		9	do	[a] 1,319
Do		10	do	[a] 1,080
Do		11	do	[a] 1,340
Do		12	SW. ¼ sec. 27, T. 19 S., R. 15 E.	[a] 1,284
Do		13	NW. ¼ sec. 27, T. 19 S., R. 15 E.	[a] 1,130
Do		14	do	[a] 1,270
Do		15	do	[a] 1,225
Do		16	do	[a] 1,229
Do		17	do	1,332
Do		18	do	1,340
Do		19	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,256
Do		20	do	1,307
Do		21	do	1,117
Do		22	do	1,144
Do		23	SE. ¼ sec. 27, T. 19 S., R. 15 E.	1,105
Do		24	SW. ¼ sec. 27. T. 19 S., R. 15 E.	1,238
Do		25	do	1,246
Do		26	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,273
Do		[b] 27	SE. ¼ sec. 27, T. 19 S., R. 15 E.	983
Do		28	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,257
Do		29	do	1,188
Do		30	do	[a] 1,275
Do		31	SW ¼ sec. 27, T. 19 S., R. 15 E.	1,194
Do		32	do	1,166
Do		33	do	1,260
Do		[b] 34	NE. ¼ sec. 27, T. 19 S., R. 15 E.	1,022
Do		35	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,168
Do		36	NE. ¼ sec. 27, T. 19 S., R. 15 E.	[a] 1,180
Do		37	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,271
Do		38	do	1,234
Do		39	do	1,225
Do		41	NW. ¼ sec. 27, T. 19 S., R. 15 E.	[a] 1,350
Do		1	SW. ¼ sec. 29, T. 19 S., R. 15 E.	1,217
Do		2	do	1,256
Do	Ætna, No. 1	1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	1,225
Do	Westmoreland, No. 1.	1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,118
Do	Forty, No 1	2	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,096
Do	Westmoreland, No. 2.	3	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,109
Do	Missouri Coalinga, No. 1.	4	do	1,150
Do	Westmoreland, No. 3.	5	do	1,085
Do	Forty, No. 3	6	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,061
Do	Pittsburg - Coalinga, No. 1.	7	do	1,080
Call		1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	1,213
Caribou Oil Mining		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,399
Do		2	do	1,356
Do		3	do	1,357
Do		4	do	1,417
Do		5	do	1,391
Do		6	do	1,400
Do		7	do	1,297
Do		8	do	1,234
Do		9	do	1,204
Do		10	do	1,233
Do		11	do	1,313
Do		12	do	1,116
Do		[b] 13	do	1,309
Carmelita		[c] 1	SE. ¼ sec. 3, T. 20 S., R. 15 E.	
Circle		[b] 1	NE. ¼ sec. 35, T. 20 S., R. 14 E.	
Claremont		1	NW. ¼ sec. 24, T. 20 S., R. 14 E.	[a] 810
Do		2	do	[a] 814

[a] Approximate. [b] Drilling. [c] Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Claremont		3	NW. ¼ sec. 24, T. 20 S., R. 14 E.	[a]805
Do		4	do	792
Do		[b]1	NE. ¼ sec. 4, T. 20 S., R. 15 E.	1,022
Coalinga	Producers and Consumers, No. 1.	[c]1	NW. ¼ sec. 20, T. 19 S., R. 15 E.	[a]1,405
Do		2	do	1,453
Do	Producers and Consumers, No. 2.	[c]2	do	[a]1,410
Do		3	do	1,453
Do	Producers and Consumers, No. 3.	3	do	1,421
Do		4	do	1,449
Do		5	do	1,465
Do		6	do	1,435
Do		7	do	1,579
Do		9	do	1,499
Coalinga Four			Sec. 4, T. 20 S., R. 15 E.	
Coalinga Mohawk		[b]1	NW. ¼ sec. 12, T. 20 S., R. 15 E.	[a]850
Coalinga Pacific		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	880
Do		2	do	883
Do		3	do	910
Do		4	do	873
Coalinga-Peerless		1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	1,362
Do		2	do	1,284
Do		3	do	1,363
Do		4	do	1,360
Do		5	do	1,260
Do		6	do	1,259
Do		7	do	1,261
Do		8	do	1,212
Do		9	do	1,224
Do		10	do	1,168
Do		11	do	1,259
Do		12	do	1,150
Coalinga Petroleum		1	NE. ¼ sec. 14, T. 20 S., R. 14 E.	870
Do		2	do	878
Do		3	do	887
Do		4	do	883
Coalinga Southern		[b]1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	920
Coalinga Western		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	968
Do		2	do	977
Do		3	do	960
Do		4	do	910
Do		5	do	887
Do		(?)6	do	960
Do		(?)7	do	869
Coast Range		1	SW. ¼ sec. 17, T. 19 S., R. 15 E.	[a]1,450
Do		2	do	[a]1,450
Do		3	do	1,451
Do		4	SE. ¼ sec. 17, T. 19 S., R. 15 E.	1,469
Do		5	SW. ¼ sec. 17, T. 19 S., R. 15 E.	1,485
Do		6	do	1,533
Commercial		[c]2	SE. ¼ sec. 12, T. 21 S., R. 14 E.	
Commercial Petroleum		1	do	869
Do		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,236
Do		2	do	1,243
Do		3	do	1,242
Do		4	do	1,253
Do		5	do	1,244
Do		6	do	1,241
Do		7	do	1,259
Do		8	do	1,254
Do		9	do	1,239
Do		10	do	1,220
Confidence		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	[a]1,280
Do		4	do	[a]1,275
Do		5	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,101
Do		6	NW. ¼ sec. 31, T. 19 S., R. 15 E.	1,240
Do		7	do	1,236
Do		8	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,251
Do		9	do	1,190
Do		10	do	1,227
Do		11	do	1,171
Do	K and C, No. 5	12	do	1,203
Do		[b]13	do	1,205
Do		[b]14	do	1,243
Consolidated Oil and Development.		[c]1	NE. ¼ sec. 10, T. 23 S., R. 16 E.	

[a] Approximate. [b] Drilling. [c] Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Crescent		a 1	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Cypress	R. H. Herren, No. 1	1	SE. ¼ sec. 1, T. 20 S., R. 14 E.	917
Do	R. H. Herron, No. 2	2	do	911
Do	R. H. Herron, No. 3	3	do	941
Do	R. H. Herron, No. 4	4	do	738
Domengine			NE. ¼ sec. 35, T. 18 S., R. 15 E.	
El Capitan (now Kern Trading and Oil).		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	
El Cerrito		b 1	NW. ¼ sec. 14, T. 23 S., R. 17 E.	
Elk		a 1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	
Ellis. (See California Diamond.)				
Esperanza Oil and Gas		1	SW. ¼ sec. 6, T. 20 S., R. 15 E.	997
Do		2	do	989
Do		3	do	972
Do		4	do	956
Do		5	do	981
Do		6	do	943
Do		b 7	do	936
Do		8	do	916
Do		a 2	SW. ¼ sec. 14, T. 22 S., R. 17 E.	
Esperanza Land and Oil		b 1	Sec. 30, T. 21 S., R. 15 E.	
Euclid		1	SW. ¼ sec. 24, T. 20 S., R. 14 E.	814
Do		2	do	824
Fauna		a 1	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Florence		a 2	NW. ¼ sec. 15, T. 22 S., R. 17 E.	
Forty. (See California Oilfield, Ltd.)				
Fresno-San Francisco		1	NE. ¼ sec. 1, T. 20 S., R. 14 E.	1,140
Do		2	do	1,128
Do		3	do	1,072
Do		4	do	1,114
Gibbs		a 1	NW. ¼ sec. 28, T. 21 S., R. 17 E.	
Golden Crest	Kreyenhagen, No. 1	b 1	NE. ¼ sec. 12, T. 22 S., R. 15 E.	
Golden State (now California Oilfields, Ltd.).		a 1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	
Graham, W. M		1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	759
Do		1	Sec. 2, T. 19 S., R. 15 E.	
Great Western		a 1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	
Guthrey		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,267
Do		2	do	1,263
Do		3	do	1,227
Do		4	do	1,242
Guthrey. (See Yellowstone.)				
Hanford		1	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,356
Do		2	do	1,379
Do		3	do	1,404
Do		4	do	1,385
Do		5	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,376
Do		6	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,387
Do		7	do	1,469
Do		8	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,341
Hawkeye State		a 2	Sec. 6, T. 21? S., 15? E.	
Henshaw. (See Sunnyside.)				
Herron, R. H. (See Cypress.)				
Highland	New York, Nos. 1 and 2.	a 2	SW. ¼ sec. 20, T. 19 S., R. 15 E.	
Home		1	NE. ¼ sec. 20, T. 19 S., R. 15 E.	c 1,490
Do		2	do	1,491
Do		3	do	1,567
Do		4	do	1,528
Do		5	do	1,597
Do		6	do	1,519
Do		7	do	1,585
Do		8	do	1,593
Inca		1	NW. ¼ sec. 24, T. 20 S., R. 14 E.	801
Do		2	do	811
Do		3	do	816
Do		4	do	799
Do		5	do	814
Do		6	do	805
Do		7	do	797
Do		8	do	805
Do		9	do	814
Do		10	do	818
Do		11	do	834
Do		12	do	870
Imperial		b 1	Sec. 2, T. 19 S., R. 15 E.	

a Abandoned. b Drilling. c Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
Independence. (See Standard.)				*Feet.*
Independent		a 1	NE. ¼ sec. 17, T. 19 S., R. 15 E	
Investment		a 1	SE. ¼ sec. 16, T. 19 S., R. 15 E	
Iowa		a 1	SW. ¼ sec. 4, T. 22 S., R. 17 E	
Jacalitos		b 1	Sec. 30, T. 21 S., R. 15 E	
K. and C. (See Confidence.)				
Kaweah. (See California Oilfields, Ltd.)				
Kern Trading and Oil		b 1	NW. ¼ sec. 35, T. 19 S., R. 15 E	
Do		1	SW. ¼ sec. 31, T. 19 S., R. 15 E	c 1,210
Do		2	do	1,234
Do		3	NW. ¼ sec. 31, T. 19 S., R. 15 E	1,222
Do		7	do	1,270
Do		8	do	1,242
Do		1	SW. ¼ sec. 25, T. 20 S., R. 14 E	811
Do		2	do	803
Keystone		a 1	NW. ¼ sec. 32, T. 19 S., R. 15 E	
Kings County		a 1	NE. ¼ sec. 3, T. 23 S., R. 16 E	
Do		a 1	SW. ¼ sec. 3, T. 23 S., R. 16 E	
Kreyenhagen		a 2	SE. ¼ sec. 32, T. 22 S., R. 16 E	
Kreyenhagen. (See Golden Crest.)				
Lorene		b 1	NW. ¼ sec. 12, T. 19 S., R. 15 E	c 825
Lucile		1	NE. ¼ sec. 6, T. 21 S., R. 15 E	770
Do		2	do	761
McCreary. (See California Oilfields, Ltd.)				
Maine State		1	NE. ¼ sec. 31, T. 19 S., R. 15 E	1,256
Do		a 2	do	c 1,300
Do		3	do	1,274
Do		4	do	1,237
Do		5	do	c 1,250
Do		6	SE. ¼ sec. 31, T. 19 S., R. 15 E	1,089
Do		7	do	1,119
Do		8	do	1,119
Do		9	do	1,154
Manchester		a 1	SW. ¼ sec. 18, T. 21 S., R. 15 E	900
Marengo		1	SW. ¼ sec. 24, T. 20 S., R. 14 E	c 790
Do		2	do	c 800
Do		3	do	c 795
Do		b 4	do	c 795
May Brothers		a 1	SE. ¼ sec. 14, T. 20 S., R. 14 E	
Mercantile Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E	1,097
Do		2	do	c 1,120
Do		3	do	1,006
Do		4	do	1,002
Michigan Oil and Development.		b 1	Sec. 17?, T. 19 S., R. 13 E	
Minnesota (now Southern Pacific R. R.)		a 2	NE. ¼ sec. 33, T. 19 S., R. 15 E	
Missouri-Coalinga. (See California Oilfields, Ltd.)				
M., K. and T		1	SW. ¼ sec. 8, T. 20 S., R. 15 E	868
Do		b 2	do	866
Montjack		a 1	NW. ¼ sec. 22, T. 19 S., R. 15 E	
Mount Hamilton Land and Oil.		a 1	SE. ¼ sec. 14, T. 21 S., R. 14 E	1,002
Mutual		a 1	SE. ¼ sec. 20, T. 19 S., R. 15 E	
Nathan. (See Porter & Scribner.)				
New Era		1	SE. ¼ sec. 12, T. 20 S., R. 14 E	
New Home		1	SE. ¼ sec. 14, T. 20 S., R. 14 E	736
Do		2	do	746
Do		3	do	737
New San Francisco Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E	1,135
Do		2	do	1,105
Do		3	do	1,068
Do		4	do	1,098
Do		5	do	1,079
New York. (See Highland.)				
Norse		1	SW. ¼ sec. 24, T. 20 S., R. 14 E	
Do		b 2	do	
Do		b 3	do	
Do		4	do	
Northeastern. (See California Oilfields, Ltd.)				

a Abandoned. b Drilling. c Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Oceanic		a 1	NW. ¼ sec. 1, T. 22 S., R. 17 E.	
Octave		1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	1,212
Do		2	do	1,208
Oil City Petroleum. (See Standard.)				
Old Keystone		a 1	SE. ¼ sec. 8, T. 19 S., R. 15 E.	
Oyama. (See California Oilfields, Ltd.)				
Ozark		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	b 850
Do		2	do	b 845
Peerless Consolidated		c 1	NE. sec. 10, T. 20 S., R. 15 E.	815
Piedmont		c 1	Sec. 24, T. 20 S., R. 14 E.	
Pennsylvania Coalinga		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	1,056
Do		2	SE. ¼ sec. 24, T. 20 S., R. 14 E.	976
Do		3	do	923
Do		4	do	975
Philadelphia and San Francisco.		1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	1,121
Do		2	do	
Do		3	do	1,107
Phoenix		a 3	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Pilot		1	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
Pittsburg		1	SW. ¼ sec. 24, T. 19 S., R. 15 E.	830
Pittsburg-Coalinga. (See California Oilfields, Ltd.)				
Porter & Scribner	Nathan lease	1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	873
Do	do	a 2	do	868
Do	do	3	do	848
Premier		1	SE. ¼ sec. 24, T. 20 S., R. 14 E.	b 790
Do		2	do	
Producers and Consumers. (See Coalinga.)				
Record		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,189
Do		2	do	1,177
Riverside (near Alcalde).				
Roanoke		a 1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	
Rock		a 1	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
St. Clair		1	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
St. Francis		c 1	SW. ¼ sec. 6, T. 21 S., R. 15 E.	b 940
St. Lawrence		a 1	NE. ¼ sec. 12, T. 23 S., R. 16 E.	
St. Paul-Fresno		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	b 950
Do		2	do	970
Do		3	do	920
Do		4	do	906
Do		5	do	910
Santa Clara		a 1	SW. ¼ sec. 30, T. 19 S., R. 15 E.	
Sauer Dough. (See Associated.)				
Section Seven		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	911
Do		2	do	915
Do		3	do	916
Do		4	do	908
Do		c 5	do	b 880
Section Six		c 1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	842
Section Ten		a 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Selma. (See Zenith.)				
Seneca		c 1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	
Shawmut		1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	878
Do		2	do	882
Do		3	do	892
Do		4	do	b 910
Do		5	do	879
Shreeve		1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	853
Standard	Independence, No. 1	1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,497
Do	Independence, No. 3	3	do	1,440
Do	Independence, No. 4	4	do	1,374
Do	Independence, No. 5	5	do	b 1,450
Do	Independence, No. 6	6	do	1,444
Do	Independence, No. 7	7	do	1,458
Do	Independence, No. 8	8	do	1,484
Do	Independence, No. 9	9	do	1,536
Do	Independence, No. 10	10	do	1,538
Do	Oil City Petroleum, No. 1.	11	SE. ¼ sec. 28, T. 19 S., R. 15 E.	1,371
Do	Oil City Petroleum, No. 2.	12	do	1,404
Do	Oil City Petroleum, No. 3.	13	do	1,372

a Abandoned. b Approximate c Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Standard	Oil City Petroleum, No. 4.	14	SE. ¼ sec. 28, T. 19 S., R. 15 E.	1,376
Do	Oil City Petroleum, No. 5.	15	do	1,448
Do	Oil City Petroleum, No. 6.	16	do	1,373
Do	Oil City Petroleum, No. 7.	17	do	1,348
Do	Oil City Petroleum, No. 8.	18	do	1,340
Do	Oil City Petroleum, No. 9.	19	do	1,361
Do	Oil City Petroleum, No. 10.	20	do	1,321
Do	Oil City Petroleum, No. 11.	21	do	1,323
Do	Oil City Petroleum, No. 12.	22	do	1,262
Do	Oil City Petroleum, No. 13.	23	do	1,211
Do	Oil City Petroleum, No. 14.	24	do	1,253
Do	Oil City Petroleum, No. 15.	25	do	1,275
Do	Twenty-eight, No. 14.	26	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,314
Do	Twenty-eight, No. 13.	27	do	1,395
Do	Twenty-eight, No. 12.	28	do	1,385
Do	Twenty-eight, No. 10.	29	do	1,241
Do	Twenty-eight, No. 11.	30	do	1,378
Do	Twenty-eight, No. 9.	31	do	1,420
Do	Twenty-eight, No. 8.	32	do	1,402
Do	Twenty-eight, No. 6.	33	do	1,256
Do	Twenty-eight, No. 5.	34	do	1,342
Do	Twenty-eight, No. 4.	35	do	1,342
Do	Twenty-eight, No. 1.	36	do	[a]1,380
Do	Twenty-eight, No. 3.	37	do	1,364
Do	Twenty-eight, No. 2.	38	do	1,428
Do	Twenty-eight, No. 7.	39	do	1,421
Do	Twenty-eight, No. 15.	40	do	1,456
Do	Twenty-eight, No. 16.	41	do	1,505
Stanislaus		[b]1	NW. ¼ sec. 4, T. 22 S., R. 17 E.	
Star		[b]1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	
Stockholders		1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,486
Do		2	do	1,385
Do		3	do	1,394
Do		4	do	1,407
Do		5	do	1,454
Stockton		[b]2	NW. ¼ sec. 30, T. 22 S., R. 18 E.	
Sunnyside	Henshaw	[c]1	SE. ¼ sec. 35, T. 20 S., R. 14 E.	
S. W. and B		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,061
Do		2	do	1,038
Do		3	do	1,031
Do		4	do	982
Tavern		[d]1	Sec. 34, T. 18 S., R. 15 E.	
T. C.		1	SW. ¼ sec. 2, T. 19 S., R. 15 E.	958
Traders		1	SW. ¼ sec. 24, T. 20 S., R. 14 E.	810
Do		2	do	818
Do		3	do	845
Do		4	do	833
Do		5	do	[a]843
Twenty-eight. (See Standard.)				
Twenty-two		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,143
Turner		[d]1	SW. ¼ sec. 2, T. 20 S., R. 15 E.	[a]1,075
Do		[d]2	do	[a]975
Union		1	NW. ¼ sec. 13, T. 20 S., R. 14 E.	812
Do		2	NE. ¼ sec. 13, T. 20 S., R. 14 E.	811
Do		3	do	810
Do		4	NW. ¼ sec. 13, T. 20 S., R. 14 E.	817
Do		5	do	808
Do		6	do	824
Do		7	do	817
Do		8	do	837
Do		9	do	835
Venus		[b]1	NW. ¼ sec. 5, T. 22 S., R. 14 E.	

[a] Approximate. [b] Abandoned. [c] Water well. [d] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Wabash		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	806
Do		2	do	802
Do		3	do	798
Do		4	do	793
Do		5	do	789
Do		6	do	787
Do		7	do	782
Do		8	do	796
Do		9	do	783
Do		10	do	779
Do		11	do	777
Do		12	do	775
Ward		1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	933
Do		2	do	934
West Coalinga (water)		1	NE. ¼ sec. 12, T. 21 S., R. 14 E.	1,052
Westlake-Rommel		*a* 3	NE. ¼ sec. 2, T. 21 S., R. 14 E.	
Westmoreland. (See California Oilfields, Ltd.)				
Whale	King	*a* 1	Sec. 4, T. 22 S., R. 14 E.	
Whittier and Green		*a* 1	NW. ¼ sec. 26, T. 20 S., R. 14 E.	
Wisconsin		*a* 1	NE. ¼ sec. 32, T. 19 S., R. 15 E.	
W. K.		1	NW. ¼ sec. 2, T. 20 S., R. 15 E.	920
Do		2	do	1,125
Do		*b* 3	NE. ¼ sec. 2, T. 20 S., R. 15 E.	*c* 960
Wright Association		*a* 1	NW. ¼ sec. 25, T. 20 S., R. 14 E.	
Yellowstone	Guthrey, No. 1	1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	917
York Coalinga		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,123
Do		2	do	1,085
Zenith	Selma, Nos. 1 and 2	*a* 2	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Zier		1	SW. ¼ sec. 1, T. 20 S., R. 14 E.	939
Do		2	do	938
Do		3	do	964
Do		4	do	970
Do		5	do	945
Do		6	do	939
Do		7	do	953

a Abandoned. *b* Drilling. *c* Approximate.

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The following list includes the more important papers relative to oil and gas published by the United States Geological Survey or by members of its staff. Those to which a price is affixed can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Any of the others (published by the Survey) can be had free by applying to the Director, U. S. Geological Survey, Washington, D. C.

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