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PRELIMINARY REPORT ON THE MCKITTRICK-SUNSET OIL REGION KERN AND SAN LUIS OBISPO COUNTIES CALIFORNIA

BY

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PRELIMINARY REPORT ON THE McKITTRICK-SUNSET OIL REGION, CALIFORNIA.

By Ralph Arnold and Harry R. Johnson.

INTRODUCTION.

GENERAL FEATURES OF THE REGION.

The region described in this report lies in western Kern and eastern San Luis Obispo counties, Cal., and embraces the northeastern flank of the Diablo and Temblor ranges, and the Carrizo and Elkhorn plains and surrounding mountain flanks. The area shown on the topographic map is a strip 75 miles long and 30 miles wide and includes about 1,800 square miles; the area geologically mapped includes between 1,500 and 1,700 square miles. The region is accessible by rail from the main lines of both the Southern Pacific and the Atchison, Topeka and Santa Fe railroads by branch lines running westward from Bakersfield to McKittrick and southwestward from Bakersfield to Maricopa and Moron. The region includes the proved productive territory of the well-known and important McKittrick, Midway, and Sunset fields, and the less important and as yet undeveloped Devils Den, Temblor, and Carrizo Plain districts. In the three most important fields the oil is believed to have originated largely in the Monterey and Santa Margarita (?) (middle Miocene) formations, and is accumulated in the porous basal portion of the unconformably overlying McKittrick (upper Miocene) formation. The Vaqueros sandstone (lower Miocene) is oil bearing in the Devils Den, Temblor, and Carrizo Plain districts.

The product of the McKittrick field is a dark-colored oil varying from 12.5° to 20° Baumé, with an average of from 15° to 18°. The production of the individual wells varies from 2 to 1,000 barrels, with an average of about 100 barrels. The production of this field was 2,517,951 barrels in 1908.

The product of the Midway field is a black to greenish-brown oil varying in gravity from 11° to 22° Baumé, with an average of 16° to 18° Baumé. The production of the individual wells is from 10 to 2,500 barrels, or possibly more, per day; the average is believed to be 100 barrels or less. The product of the Midway field was 410,393 barrels in 1908.

The Sunset field yields a black oil varying in gravity from 11° to 20° Baumé, most of it best adapted for fuel and road oil. The production of the individual wells is from 4 to 400 barrels per day; the average for the field is about 100 barrels per day. In 1908 the Sunset field produced 1,556,263 barrels of oil.

The oil of these fields is transported largely by tank cars, although a pipe line (that of the Standard Oil Company) taps the McKittrick and Midway districts and two other pipe lines to serve all three fields are now in course of construction. The oil is used largely for fuel, road dressing, and refining for asphalt.

SETTLEMENT.

The earliest mention of the region occurs in some of the annals of the Spanish padres, among whom Garces [a] is a notable example. This zealous worker for the spread of Spanish influence crossed the Temblor or the Mount Pinos Range somewhere in the neighborhood of Sunset, in the spring of 1776, during an exploration for the site of a mission in the Great Valley.

Although the petroleum deposits have long been known, practically all of the development has come within the past twenty years, and most of it during the last ten years. Except locally, the region is not at present valuable for agricultural purposes, and in consequence settlements are few. The population of the region has increased rapidly within the past two years, owing to the rejuvenation of the oil industry, so that at present, while actual figures are not at hand, there are probably over 3,000 people resident in the territory.

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.[b] 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 bulletin was instructed to complete the work begun by Mr. Eldridge, and by the fall of 1908 detailed reports on all of the oil

[a] Coues, Elliott, On the trail of a Spanish pioneer, vol. 1, pp. 272-280.

[b] 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 McKittrick, Midway, and Sunset districts is on pp. 308-310.)

districts in the counties bordering the coast, and also on the Coalinga oil district, immediately north of the region covered by the present report, had been issued.[a]

The summer and fall of 1908 were spent by the writers in making a more or less detailed geologic investigation of the McKittrick, Midway, and Sunset districts, together with a detailed reconnaissance of the rest of the region covered by the present report, which includes what have been called the Devils Den, Lost Hills, Bitterwater, Carneros, and Carrizo Plain districts. The territory in the extreme southwestern part of the region covered by the McKittrick-Sunset map, including the Caliente Range, was not visited, owing to lack of time. 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 bulletins containing more elaborate maps, sections, and other illustrations, and chemical analyses and calorific tests of a large number of the oils. The location of the McKittrick-Sunset region and the other oil districts of southern California are shown in figure 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 too technical and as not easily comprehensible by the ordinary reader, but the treatment adopted is the only consistent one for a subject that involves 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 of the numerous text-books of geology.[b]

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[a] 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.

Arnold, Ralph, and Anderson, Robert, Preliminary report on the Coalinga oil district, Fresno and Kings counties, Cal.: Bull. U. S. Geol. Survey No. 357, 1908.

Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga oil district, Fresno and Kings counties, Cal.: Bull. U. S. Geol. Survey No. 398, 1910.

[b] 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.

CONDITIONS LIMITING ACCURACY OF MAPS.

In using the preliminary geologic map which accompanies this report, the following facts must be kept constantly in mind:

First, the map is based upon a reconnaissance which permitted to the topographers to whom the mapping was intrusted a certain lati-

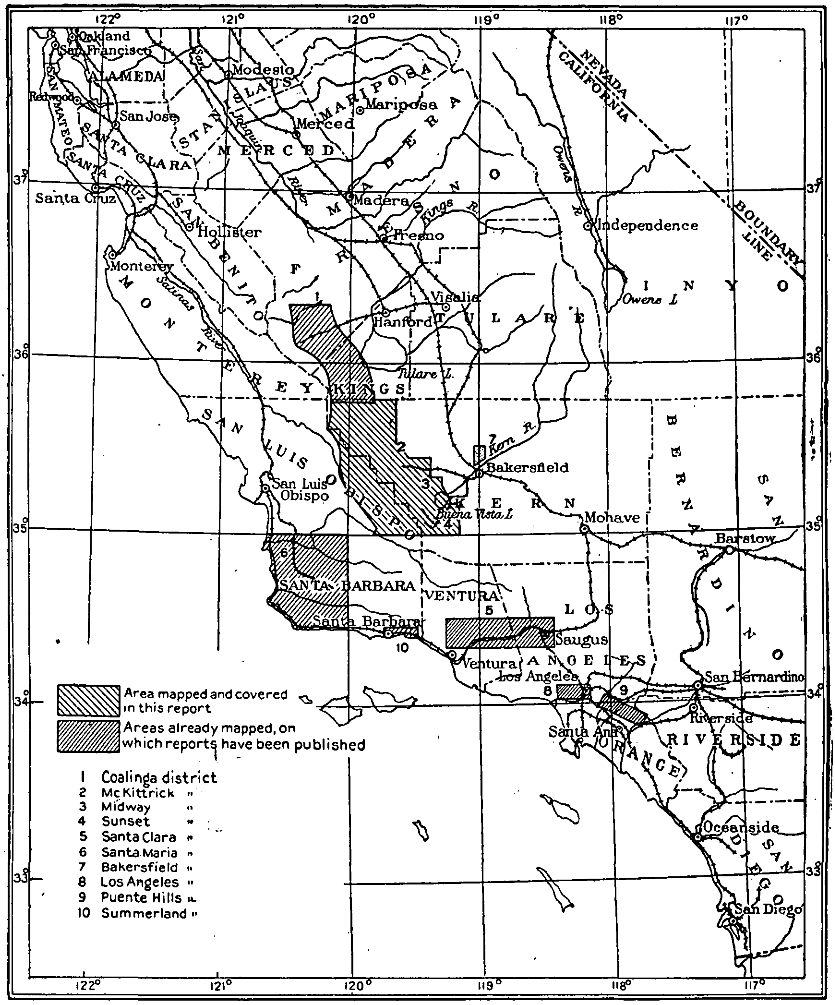

FIGURE 1.—Index map of a part of California, showing position of McKittrick-Sunset region.

tude in the degree of accuracy required. The exactness of a detailed special map is therefore not to be expected either in contouring or in location of cultural features.

Second, where contacts between various formations, or structural lines, are clearly defined in the field, they have been located with as close an approach to accuracy as the scale of the map will allow.

At some places conditions are so indefinite that much less accuracy in drawing contacts, etc., has been possible, and symbols indicative of indefinite contacts, faults, and folds have been necessary. Throughout the whole region studied geologic features have been indicated almost wholly with reference to contouring, drainage, houses, and roads.

Third, the factor that most limits the proper use of the geologic map is the inaccuracy of many of the land lines in this region. Many of the surveys were originally poor; few of the original corners either of sections or townships can now be found; and in some portions of the region as many as five additional surveys, none of which tie, have been made in private, and usually abortive, efforts to locate property lines correctly. It has therefore been impossible everywhere upon the accompanying map to correctly delineate section and township lines with reference to contouring, drainage, houses, and roads, and consequently with reference to geologic features. Since the classification of the region into mineral and nonmineral land must be referred to sections and townships, although based upon geologic evidence, an element of great uncertainty is introduced; this must be allowed for in any consideration of the classification. These inconsistencies can be adjusted only by a resurvey by the United States Land Office of the region involved.

PREVIOUS KNOWLEDGE OF THE REGION.

Reference to the geology and oil resources of the McKittrick-Sunset region is made more particularly in the following publications, besides the Pacific Railroad Reports (1856, etc.), and the Whitney State Survey Reports (1864, etc.):

1894. WATTS, W. L. The gas and petroleum yielding formations of the central valley of California. Bull. California State Min. Bur. No. 3, 100 pp., maps, plates, and figures. Sacramento.

Notes on the topography, geology, and oil resources of the Sunset district will be found on pp. 22–37, and on the McKittrick district (called the Buena Vista district in Watts's report) on pp. 41–53; some analyses of water from the region are on pp. 90 and 91.

1900. WATTS, W. L. Oil and gas yielding formations of California. Bull. California State Min. Bur. No. 19, 236 pp., maps, plates, and figures. Sacramento.

Additional notes to those given in his former report will be found as follows: Geologic sketch of San Joaquin Valley, pp. 106–109; Sunset district, pp. 117–125; McKittrick district, pp. 125–131; Devils Den district, pp. 131 and 132.

1904. COOPER, H. N. Chemical analyses of California petroleum. Bull. California State Min. Bur. No. 31 (also inserted as appendix in Bull. No. 32). Sacramento.

Analyses of oil from the McKittrick, Sunset, and Temblor districts are given in this table.

1904. PRUTZMAN, PAUL W. Production and uses of petroleum in California. Bull. California State Min. Bur. No. 32, 230 pp., maps, plates, figures, and tables. Sacramento.

Maps of the various districts and analyses and notes concerning the physical and chemical properties of the oils, their uses, methods of refining, and other useful data are given in this bulletin.

1905. ANDERSON, FRANK M. A stratigraphic study in the Mount Diablo Range of California. Proc. California Acad. Sci., 3d ser., Geology, vol. 2, pp. 156–248, pls. 13 to 35, 1 map. San Francisco.

This paper includes a brief discussion of the geology and paleontology of the region along the southwestern side of the San Joaquin Valley, including the region from Devils Den to Sunset, together with descriptions and illustrations of many of the fossils found in the Tertiary formations.

1908. ANDERSON, FRANK M. A further stratigraphic study in the Mount Diablo Range of California. Proc. California Acad. Sci., 4th ser., vol. 3, pp. 1–40. San Francisco.

In this paper Mr. Anderson gives a résumé of his former one and makes some corrections regarding the age of certain of the formations necessitated by a further study of the regions.

1910. ARNOLD, RALPH, and ANDERSON, ROBERT. Geology and oil resources of the Coalinga district, Fresno and Kings counties, Cal. Bull. U. S. Geol. Survey No. 398. 354 pp., maps, plates, figures, and tables.

This report includes a discussion of the geology and oil resources of the region immediately adjacent on the north to that covered by the present report. Many of the discussions apply to the McKittrick-Sunset region.

ACKNOWLEDGMENTS.

The writers wish to acknowledge their indebtedness to the late George H. Eldridge for notes collected by him during his examination of the region in 1901 and 1902. These notes were taken at a time when a considerable amount of information concerning the early development work in the districts was available. Many of the data concerning the wells put down in these early days have since been destroyed, and but for Mr. Eldridge's notes a considerable part of the value of the present report would have been lost. Acknowledgment is also due to other previous workers in the region, among whom are W. L. Watts, Frank M. Anderson, and Robert Anderson.

The value and accuracy of a report like the present one, including as it does the 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 in a given territory with those in other better-known fields may also be of great assistance; but for furnishing definite information regarding the occurrence of the oil in any particular area there is just one instrument that may be relied upon, and that is the drill.

From the drilling of wells in the region under discussion during the last sixteen years a large body of useful data concerning the underground conditions has been accumulated, and whatever accuracy and value there is in the underground contour maps and in the statements concerning the geology of the wells in this report is due almost entirely to the generosity of the operators 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. W. R. Hamilton, P. A. Williams, H. S. Williams, F. C. Ripley, W. W. Orcutt, W. B. Moore, J. M. Atwell, H. G. Ball, Martin Barber, Orlando Barton, A. H. Butler, H. C. Mosher, Ed. S. Mosher, Walter Snook, W. E. White, Frank M. Anderson, E. H. Andrews, R. L. Atkins, S. G. Atkinson, W. T. Baldwin, Arthur F. L. Bell, R. P. Benedict, C. J. Berry, R. W. Bess, Bernard Bienenfeld, H. L. Black, E. J. Boust, William Brown, Charles F. Burks, E. D. Burge, A. B. Canfield, Clayton I. Chandler, C. L. Cole, J. H. Crafts, L. Creason, Angus J. Crites, Charles Dickinson, R. E. Diggins, the late E. Erickson, Michel Erume, D. R. Evinger, R. N. Ferguson, Mrs. A. W. Gilfillan, R. E. Graham, Henry A. Greene, S. A. Guiberson, jr., H. D. Guthrey, M. L. Harding, C. J. Harvey, R. L. Heber, W. H. Hudgins, W. B. Isaacs, D. A. Jackson, F. L. Keller, J. P. Kerr, G. T. Kincaid, L. J. King, K. King, David Kinsey, J. E. Koeberle, S. G. Lamb, B. F. Levet, A. L. Linneman, M. E. Lombardi, Ed. N. Moore, F. L. Matson, J. A. McClurg, jr., W. G. McCutcheon, J. C. McDonald, J. J. McLimans, D. E. Martin, E. J. Miley, Irving Miller, T. H. Miner, C. J. Murphy, G. R. Neill, John H. Osgood, W. K. Osmer, G. W. Pickle, A. E. Preston, J. E. Prether, George Quarré, S. D. Rankin, G. A. Reynolds, J. A. Reynolds, W. D. Roberts, L. A. Rose, W. J. Schultz, F. N. Scofield, C. V. Scott, I. E. Segur, J. J. Shupe, H. H. Smith, James M. Smith, R. M. Smith, M. A. Spellacy, Martin J. Spellacy, Timothy Spellacy, G. E. Squires, C. W. St. Louis, B. K. Stroud, Richard Syke, S. G. Tryon, T. O. Turner, F. F. Weed, T. J. Whaley, H. G. Whittikin, Claude Wilson, 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, chief geographer, for assistance rendered in connection with the preparation of the topographic map upon which this report is based.

In a country where even the bare necessities of existence are often hard to obtain one usually finds the truest hospitality. The writers therefore take pleasure in extending thanks to the following, in addition to many of those mentioned above, who extended hospitalities or in other ways facilitated the field work: Warren Rogers, Orris Castell, Robert Potter, W. M. Cook, O. H. Tetzlaff, Edward A. Connors, Mrs. Ed. Still, P. D. Cash, John L. Aramburu, A. E. Gordon, Maddux Brothers, Joseph E. Orchard, and E. E. Morgan.

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GEOGRAPHY AND TOPOGRAPHY.

LOCATION.

The country mapped and discussed in this report as the McKittrick-Sunset oil region lies within or along the northeastern edge of the Coast Ranges of California adjacent to the great interior San Joaquin Valley, and comprises the southernmost part of the Diablo Range, the Temblor Range, the Buena Vista and Elk hills, the Caliente Range, and the Carrizo Plain. This region is included between 119° 10′ to 120° 10′ west longitude and 35° to 35° 50′ north latitude. Roughly, this tract of land, about 75 miles long and 30 miles wide, has an area of about 1,800 square miles. Reference to the key map (fig. 1) will show the position of the region with respect to other oil-producing districts of the State.

The developed oil territory commonly referred to as the McKittrick, Midway, Sunset, Temblor, and Devils Den districts lies along the northeastern flank of the Temblor and Diablo ranges, while the Carrizo Plain district occupies the southwestern flank of the Temblor Range adjacent to the Carrizo Plain. The post-offices Simmler, in San Luis Obispo County, and Dudley, Annette, McKittrick, Taft, Maricopa, and Midland, in Kern County, lie within or just outside of the region; the towns and railroad stations McKittrick, Moron, (post-office, Taft) Monarch (post-office, Maricopa), Midoil (post-office, Midland), Fellows or Siding No. 4 (post-office, Midland), and Hazelton (post-office, Maricopa), are also within its borders. A railroad line connects McKittrick with the Southern Pacific and the Atchison, Topeka and Santa Fe railroads at Bakersfield, and another line connects Fellows, Midoil, Moron, Monarch, and Hazelton with the same roads also at Bakersfield. Wagon roads enter the region from Coalinga and Lemoore on the north by way of the Kettleman and Antelope plains; from the Salinas Valley country on the west by Cottonwood Pass, by Polonio Pass and the Antelope Valley, by Palo Prieto Pass and Bitterwater Valley, and by way of La Panza, San Juan River, and Carrizo Plain; from the San Joaquin Valley on the east by way of the Antelope Plain at the south end of the Lost Hills, by way of Lokern north of the Elk Hills, and by routes both north and south of Buena Vista Lake; and from the mountains on the south by way of Maricopa Valley.

DESCRIPTION OF PLACE NAMES.

It is important that the names of the various places and features 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). Township and range numbers south and east refer to the Mount Diablo base and meridian. Numbers north and west refer to the San Bernardino base and meridian.

Aido Spring.—This name is used for the sulphur spring in the N. ½ sec. 35, T. 25 S., R. 17 E.

Alamo Solo Springs.—The well-established name for springs at a lone cottonwood near the center of sec. 2, T. 25 S., R. 18 E.; means "lone cottonwood" springs.

Antelope Hills.—This name is proposed to include the group of low hills lying in the SW. ¼ T. 27 S., R. 20 E., and the N. ½ T. 28 S., R. 20 E. These hills are a range for the few wild antelope left in this region.

Aramburu Canyon.—This is the locally accepted name for a canyon lying in sec. 13, T. 30 S., R. 20 E. It is named for a Portuguese settler, John L. Aramburu, residing at the mouth of the canyon.

Barril Valley.—Lies in about the center of T. 26 S., R. 17 E., and opens into Franciscan Creek (to be described later).

Barton's.—The name applied to a group of buildings, including the cabin of Orlando D. Barton, an old settler, in the N. ½ sec. 23, T. 25 S., R. 18 E.

Barton Hills.—An irregular group of hills lying almost entirely in the S. ½ T. 25 S., R. 18 E. Named for the gentleman mentioned in the last paragraph, who has made this region his study for many years.

Bitter Creek.—An intermittent stream heading in the SW. corner of T. 11 N., R. 24 W., and flowing diagonally northeast across the township. The quality of the water gives the name to this creek.

Bitterwater Creek.—A long, intermittent stream heading in the southeast corner of T. 28 S., R. 18 E., flowing due northwest across the township, thence turning northeast and emptying into the San Joaquin Valley in the NW. ¼ T. 27 S., R. 19 E. This name also is derived from the quality of the creek water.

Bitterwater Valley.—The valley of Bitterwater Creek from the southwest corner of T. 27 S., R. 18 E., to its debouchment.

Buena Vista Hills.—This name is proposed for the low ridge extending from the NE. ¼ T. 32 S., R. 24 E., northwestward to the northwest corner of T. 31 S., R. 23 E.

Buena Vista Valley.—The gravel-filled depression lying between the two ranges comprising Buena Vista Hills and the Elk Hills. The names of this valley and of the range to the south are proposed because of their proximity to Buena Vista Lake.

Carneros Spring.—The only available source of drinking water along the road between Dudley and McKittrick; long known variously as Canary, Canaris, Carnaros, and Carnaris. The origin of the name is definitely established now as referring to a sheep camp which formerly existed here, and the spelling "Carneros" is preferred. The spring lies in sec. 5, T. 29 S., R. 20 E.

Carneros Canyon.—The name long used for the well-marked canyon heading in the NE. ¼ T. 29 S., R. 19 E., and trending northeastward into sec. 20, T. 28 S., R. 20 E., where it enters the San Joaquin Valley.

Carnaza Creek.—The name applied to a creek which flows southwestward across the E. ½ T. 28 S., R. 17 E., and into which flows Carnaza Spring. These names are of local application.

Cottonwood Creek.—An intermittent stream flowing into McLure Valley from the northern part of T. 25 S., R. 17 E.

Cottonwood Pass.—The pass between the McLure and Cholame valleys at the head of Cottonwood Creek.

Crocker Flat.—The name proposed for an area lying mostly in secs. 19 and 30, T. 31 S., R. 22 E.

Devils Den.—The name applied to the vicinity of a peculiar rock cropping in sec. 20, T. 25 S., R. 18 E.

Devilwater Creek.—The name of an intermittent stream flowing northeastward through the N. ½ T. 28 S., R. 19 E. Origin probably traceable to the unsavory character of the water.

Elk Hills.—The name proposed for the low range almost wholly included in T. 30 S., R. 23 E.; T. 30 S., R. 24 E.; T. 31 S., R. 23 E.; and T. 31 S., R. 24 E. The few remaining elk in this region are said to range in these hills.

Elkhorn Hills.—The name proposed for a group of hills extending northwestward across T. 11 N., R. 25 W.

Elkhorn Scarp.—The name proposed for the terrace-like escarpment extending from the southeast corner of T. 11 N., R. 25 W., northwestward across T. 12 N., R. 26 W., T. 32 S., R. 22 E., and T. 32 S., R. 21 E., into the SW. ¼ T. 31 S., R. 21 E. This feature is purely structural, following the great San Andreas fault or rift, and hence the application of the term "scarp."

Emigrant Hill.—The name locally applied to an isolated point in sec. 24, T. 25 S., R. 18 E. This hill is said to have been a landmark for the traveler in this region in the earlier days.

Franciscan Creek.—The name proposed for the intermittent stream flowing northeastward across the SE. ¼ T. 26 S., R. 17 E. Rocks of the Franciscan formation exist along the stream.

Frazer Valley.—The name proposed for a partly inclosed depression in the hills south of Frazer Spring and lying mostly in secs. 2 and 3, T. 30 S., R. 21 E.

Gould Hills.—The name proposed, after a pioneer operator, for hills north of the Temblor Valley and lying in the northern part of T. 29 S., R. 20 and 21 E.

Los Yeguas Creek.—The name applied locally to the stream heading in sec. 30, T. 28 S., R. 19 E., and flowing southwestward into Bitterwater Creek. Formerly many brood mares were pastured about the head of this stream. The name means "the mares."

Maricopa Valley.—The name proposed for the partly structural depression through which Bitter Creek flows. This valley lies in the central portion of T. 11 N., R. 24 W.

McKittrick Summit.—The name proposed for the 4,323-foot point in the N. ½ sec. 30, T. 30 S., R. 21 E.

McKittrick Valley.—The name proposed for the depression which extends northwestward through T. 30 S., R. 22 E., and in which lies the town of McKittrick.

McGovern Gap.—The name locally applied to a natural gateway in the hills in sec. 4, T. 26 S., R. 17 E. A settler named McGovern resides near this point.

Media Agua Creek.—The name applied locally to a stream flowing approximately north through the central part of T. 28 S., R. 19 E.; means "middle water" creek (halfway between Carneros Spring and a well at Point of Rocks).

Midway Peak.—A 3,651-foot point in sec. 4, T. 32 S., R. 22 E. Named from proximity to Midway oil field.

Midway Valley.—An alluvial depression extending from the south-central portion of T. 32 S., R. 24 E., northwestward into the N. ½ T. 31 S., R. 22 E. It lies between Buena Vista Hills and the main Temblor Range, and is named for its proximity to the Midway oil field.

Miller Flats.—The name proposed for the rolling uplands lying mostly within the NE. ¼ T. 27 S., R. 17 E. Named for James Miller, an old settler in this region.

Orchard Peak.—The name proposed for the summit in sec. 22, T. 25 S., R. 17 E. Named for Joseph E. Orchard, an old resident of the McLure Valley.

Palo Prieto Pass.—A long-standing name for the narrow trough-like pass extending from the middle of T. 27 S., R. 17 E., northwestward into T. 26 S., R. 16 E.

Polonio Pass.—The name applied to the low pass at the head of Antelope Valley, lying mostly within T. 25 S., R. 17 E.

Panorama Hills.—The name proposed for the low range extending from the northeast corner of T. 32 S., R. 21 E., northwestward to sec. 7, T. 31 S., R. 21 E.

Panorama Point.—A conspicuous hill in sec. 34, T. 31 S., R. 21 E. This name has been used for some years by E. W. White, a settler in the region.

Pyramid Hills.—This range of hills is more accurately defined south of Dagany Gap, as including the ridges which extend southeastward from sec. 2, T. 25 S., R. 18 E., to and including Emigrant Hill.

Raven Pass.—The local name for the low pass in sec. 30, T. 26 S., R. 18 E.

Salt Spring.—The well-known local name of the saline tar spring on the north line of sec. 25, T. 25 S., R. 18 E.

Sandiego Joe's.—The name of a ranch in sec. 8, T. 30 S., R. 20 E., in Sandiego Canyon.

Santos Creek.—A name derived from that of an old settler, Joe Santos, and applied locally to a short stream flowing northeastward through the SE. ¼ T. 28 S., R. 19 E., and joining Carneros Creek.

Santa Maria Valley.—The local name of a depression extending northwestward through the central part of T. 30 S., R. 21 E.

Sawtooth Ridge.—The name proposed for a ridge lying mostly in sec. 1, T. 26 S., R. 17 E. This name is applied because of the jagged topography there.

Shale Hills.—The name proposed for the group of hills lying in the NE. ¼ T. 27 S., R. 18 E., and that portion of the S. ½ T. 26 S., R. 18 E., which lies northeast of Raven Pass.

Shale Point.—This name is proposed for the low ridge in the NE. ¼ sec. 7, T. 27 S., R. 19 E.

Spellacy Hill.—The name proposed for the rather isolated hill lying mostly in secs. 22, 23, 24, 25, and 26, of T. 32 S., R. 23 E. Spellacy Brothers, of Los Angeles, were among the earlier oil investors prominently connected with the development of the territory in this vicinity.

Syncline Hill.—The name proposed for a prominent structural feature lying in the SE. ¼ T. 29 S., R. 17 E.

Vishnu well.—The name applied to an oil well in sec. 22, T. 32 S., R. 22 E.

GENERAL TOPOGRAPHIC FEATURES.

Although there is great diversity in the relief of the region, the arid climate in this latitude exerts a definite control over the topography, so that original structural features, the results of mountain-building activities, have been remarkably preserved throughout. Drainage lines are usually sharply incised and the uplands are often marked by steep slopes. The lowlands are characterized by the broad, gently sloping, gravelly fans resulting from the intermittent precipitation of an arid country.

Diablo Range.—The southern extremity of the chain of ridges of the Diablo Range, so important topographically in the Coalinga district, terminates in the north end of the present region as a rugged, somber spur reaching an elevation of about 3,000 feet. Associated with the Diablo Range are the much lower structural ridges of the Pyramid and Kettleman hills which lie to the east.

Temblor Range.—This range, which is the dominating feature of the region, lies at its north end en échelon with the Diablo Range and coalesces with the Mount Pinos group of mountains toward the south. It has a true northwest and southeast direction, and preserves a uniform width of about 7 miles and a broadly even summit line, which reaches its greatest elevation of 4,300 feet west of McKittrick. The southwest slope of the range is steep and through most of its length sharply demarked from the flat Carrizo Plain, while the northeast slope descends in a series of irregular tiers of hills, the lowest of which merge gently into the fans of the San Joaquin Valley.

Buena Vista and Elk Hills.—This group of hills occupies a roughly elliptical area northeast of the Temblor Range, between McKittrick and Buena Vista Lake. It includes two ranges elongated in a direction somewhat north of west and separated by a gravel-filled depression. These hills reach an elevation of about 1,500 feet. Like all of the lower relief in the region, they are barren of all except low-growing vegetation—grasses and sagebrush.

Carrizo Plain.—This great inclosed depression, lying along the southwestern side of the Temblor Range and between it and the Caliente Range, has a length of about 50 miles and a width at its lowest portion of about 7 miles, but gradually tapers toward the southeast to less than one-third this width at a point several miles southwest of Maricopa. The plain has an elevation of 2,000 to 2,500 feet.

San Joaquin Valley.—A portion of the margin of this great valley lies within the region under discussion. It is an area of coalescent alluvial fans which slope gently downward toward the northeast from the lower hills of the Temblor and Diablo ranges. At several points are reentrants of the valley, notably at Antelope Valley, which separates the Temblor and Diablo ranges, and at Buena Vista and Midway valleys. The western margin of the San Joaquin Valley has an elevation of about 1,000 feet.

LAND CLASSIFICATION.

The following areas within the McKittrick-Sunset oil region have been classified as mineral lands and such of these as yet belong to the Government have been withdrawn from all kinds of entry, "pending consideration of the question of legislation upon the subject, unless it be shown by reclassification or sufficient evidence that any particular tract or tracts thereof do not in fact contain oil." Lands classified as mineral include all those lying between the surface outcrop of the bottom of the lowest oil-bearing formation (Vaqueros) and a line marking the limits of the area in which the uppermost productive oil zone can be reached by a well 5,000 feet or less deep. This margin is indicated on the geologic map accompanying this report by a heavy blue line.

Lands classified as oil lands.

[Mount Diablo base and meridian.]

T. 25 S., R. 18 E.:
- Sec. 1: W. ½ and SE. ¼ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
- Sec. 2: All.
- Sec. 3: E. ½.
- Sec. 8: S. ½ of SE. ¼.
- Sec. 9: S. ½ of S. ½.
- Sec. 10: E. ½ of NE. ¼, S. ½ of SW. ¼, SW. ¼ and E. ½ of SE. ¼.
- Sec. 11: All.
- Sec. 12: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 13, 14, 15, and 16: All.
- Sec. 17: E. ½, E. ½ of NW. ¼.
- Sec. 20: NE. ¼ of NE. ¼.
- Sec. 21: N. ½.
- Sec. 22: N. ½, NE. ¼ of SW. ¼, NW. ¼ of SE. ¼.
- Sec. 23: N. ½, N. ½ of S. ½.
- Sec. 24: All.
- Sec. 25: E. ½, NE. ¼ of NW. ¼.
- Sec. 36: NE. ¼, E. ½ of NW. ¼, N. ½ and SE. ¼ of SE. ¼.

T. 25 S., R. 19 E.:
- Secs. 1 and 2: All.
- Sec. 3: E. ½, NW. ¼, N. ½ and SE. ¼ of SW. ¼.
- Sec. 4: NE. ¼ of NE. ¼.
- Sec. 7: SW. ¼ of SW. ¼.
- Sec. 10: NE. ¼.
- Sec. 11: E. ½, NW. ¼, N. ½ and SE. ¼ of SW. ¼.
- Secs. 12 and 13: All.
- Sec. 14: NE. ¼, NE. ¼ of NW. ¼, NE. ¼ of SE. ¼.
- Sec. 18: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ of SE. ¼.
- Sec. 19: All.
- Sec. 20: SW. ¼ of NW. ¼, W. ½ and SE. ¼ of SW. ¼.
- Sec. 24: NE. ¼, E. ½ of NW. ¼, E. ½ and NW. ¼ of SE. ¼.
- Sec. 25: NE. ¼ of NE. ¼.
- Sec. 29: W. ½.
- Secs. 30 and 31: All.
- Sec. 32: W. ½ and SE. ¼ of SE. ¼, W. ½.

T. 25 S., R. 20 E.:
- Sec. 6: SW. ¼ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
- Sec. 7: All.
- Sec. 8: SW. ¼ of NW. ¼, W. ½ and SE. ¼ of SW. ¼.
- Sec. 17: W. ½ of NE. ¼, W. ½, SE. ¼.
- Secs. 18, 19, and 20: All.
- Sec. 21: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
- Sec. 27: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ of SE. ¼.
- Secs. 28 and 29: All.
- Sec. 30: E. ½, NW. ¼, E. ½ of SW. ¼.
- Sec. 31: E. ½ of NE. ¼.

T. 25 S., R 20 E.—Continued.
Sec. 32: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
Secs. 33 and 34: All.
Sec. 35: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
T. 26 S., R. 19 E.:
Sec. 4: SW. ¼ of NW. ¼, SW. ¼.
Sec. 5: All.
Sec. 6: NE. ¼, E. ½ and NW. ¼ of NW. ¼, E. ½ and NW. ¼ of SE. ¼.
Sec. 8: E. ½, NW. ¼, NE. ¼ of SW. ¼.
Sec. 9: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 16: N. ½.
Sec. 17: NE. ¼ of NE. ¼.
T. 26 S., R. 20 E.:
Sec. 1: S. ½ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
Secs. 2 and 3: All.
Sec. 4: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
Sec. 5: E. ½ and NW. ¼ of NE. ¼.
Sec. 9: E. ½ and NW. ¼ of NE. ¼.
Secs. 10 to 14, inclusive: All.
Sec. 15: NE. ¼, NE. ¼ of NW. ¼, NE. ¼ of SE. ¼.
Sec. 23: NE. ¼, NE. ¼ of NW. ¼, NE. ¼ of SE. ¼.
Sec. 24: All.
Sec. 25: NE. ¼, NE. ¼ of NW. ¼.
T. 26 S., R. 21 E.:
Sec 7: SW. ¼ of NW. ¼, W. ½ and SE. ¼ of SW. ¼.
Sec. 18: SW. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 19: All.
Sec. 20: W. ½ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
Sec. 29: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 30: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼
Sec. 31: NE. ¼ of NE. ¼.
Sec. 32: N. ½.
T. 28 S., R. 19 E.:
Sec. 12: SE. ¼ of SE. ¼.
Sec. 13: E. ½ of NE. ¼, SE. ¼.
Sec. 24: E. ½.
Sec. 25: NE. ¼, NE. ¼ of SE. ¼.
T. 28 S., R. 20 E.:
Sec. 7: S. ½ of S. ½.
Sec. 8: S. ½ of SW. ¼.
Sec. 15: SW. ¼, S. ½ of SE. ¼.
Sec. 16: S. ½ of NE. ¼, W. ½, SE. ¼.
Secs. 17 to 22, inclusive: All.
Sec. 23: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
Sec. 25: W. ½ of NW. ¼, SW. ¼.
Secs. 26 to 30, inclusive: All.
Sec. 31: NE. ¼, E. ½ of NW. ¼, N. ½ of SE. ¼.
Secs. 32 to 35, inclusive: All.
Sec. 36: W. ½ of NE. ¼, W. ½, SE. ¼.
T. 29 S., R. 19 E.:
Sec. 23: SE. ¼, SE. ¼ of SW. ¼.
Sec. 24: SW. ¼, W. ½ and SE. ¼ of SE. ¼.
Sec. 25: All.
Sec. 26: E. ½, E. ½ of NW. ¼.

T. 29 S., R. 19 E.—Continued.
- Sec. 35: NE. ¼ of NE. ¼.
- Sec. 36: N. ½, NW. ¼, E. ½ of SE. ¼.

T. 29 S., R. 20 E.:
- Secs. 1, 2, and 3: All.
- Sec. 4: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
- Sec. 9: NE. ¼, E. ½ of NW. ¼, E. ½ of SE. ¼.
- Secs. 10, 11, and 12: All.
- Sec. 13: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
- Sec. 14: N. ½, W. ½ and NE. ¼ of SW. ¼, N. ½ of SE. ¼.
- Sec. 15: NE. ¼, E. ½ and NW. ¼ of NW. ¼, NE. ¼ of SW. ¼, NW. ¼ and E. ½ of SE. ¼.
- Sec. 24: E. ½, SW. ¼ and E. ½ of NW. ¼, NE. ¼ of SW. ¼.
- Sec. 25: E. ½, E. ½ and SW. ¼ of NW. ¼, E. ½ and NW. ¼ of SW. ¼.
- Sec. 26: SW. ¼ of SW. ¼.
- Sec. 27: SW. ¼, W. ½ and SE. ¼ of SE. ¼.
- Sec. 28: S. ½ of NW. ¼, S. ½.
- Sec. 29: S. ½ of NE. ¼, W. ½, SE. ¼.
- Secs. 30 to 36, inclusive: All.

T. 29 S., R. 21 E.:
- Sec. 4: SW. ¼, SW. ¼ of SE. ¼.
- Sec. 5: S. ½ of NW. ¼, S. ½.
- Sec. 6: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 7, 8, and 9: All.
- Sec. 10: SW. ¼ of NW. ¼, W. ½ and SE. ¼ of SW. ¼.
- Sec. 15: W. ½ of NE. ¼, W. ½, W. ½ and SE. ¼ of SE. ¼.
- Secs. 16 to 22, inclusive: All.
- Sec. 23: SW. ¼ of NW. ¼, SW. ¼, S. ½ of SE. ¼.
- Sec. 24: S. ½ of SW. ¼.
- Secs. 25 to 36, inclusive: All.

T. 29 S., R. 22 E.:
- Sec. 29: SW. ¼ of SW. ¼.
- Sec. 30: S. ½ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
- Sec. 31: All.
- Sec. 32: SW. ¼ of NE. ¼, W. ½, W. ½ and SE. ¼ of SE. ¼.

T. 29 S., R. 23 E.:
- Sec. 31: S. ½ of SE. ¼.
- Sec. 32: S. ½ of NE. ¼, SE. ¼ of NW. ¼, S. ½.
- Sec. 33: All.
- Sec. 34: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Sec. 35: S. ½ of NW. ¼, S. ½.
- Sec. 36: W. ½ and SE. ¼ of SW. ¼, SW. ¼ of SE. ¼.

T. 30 S., R. 20 E.:
- Secs. 1 to 5, inclusive: All.
- Sec. 6: NE. ¼, NW. ¼ and E. ¼ of NE. ¼, NW. ¼ and E. ½ of SE. ¼.
- Sec. 8: E. ½, NW. ¼, NE. ¼ of SW. ¼.
- Secs. 9 to 16, inclusive: All.
- Sec. 17: NW. ¼ and E. ½ of NE. ¼, E. ½ of SE. ¼.
- Sec. 21: E. ½, NW. ¼, NW. ¼ and E. ½ of SW. ¼.
- Secs. 22 to 26, inclusive: All.
- Sec. 27: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
- Sec. 28: E. ½ and NW. ¼ of NE. ¼.
- Sec. 34: N. ½ of NE. ¼.
- Sec. 35: E. ½, NW. ¼, NE. ¼ of SW. ¼.
- Sec. 36: All.

T. 30 S., R. 21 E.: All.
T. 30 S., R. 22 E.:
Sec. 1: S. ½ of NE. ¼, S. ½.
Sec. 2: S. ½ of SW. ¼, SE. ¼.
Sec. 3: SW. ¼, S. ½ of SE. ¼.
Sec. 4: SW. ¼ of NE. ¼, W. ½ and SE. ¼ of NW. ¼, S. ½.
Secs. 5 to 36 inclusive: All.
T. 30 S., R. 23 E.: All.
T. 30 S., R. 24 E.:
Sec. 6: S. ½ of NW. ¼, S. ½.
Sec. 7: All.
Sec. 8: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 9: SW. ¼ of NW. ¼, SW. ¼, S. ½ of SE. ¼.
Sec. 14: SW. ¼ of SW. ¼.
Sec. 15: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
Secs. 16 to 22 inclusive: All.
Sec. 23: S. ½ of NE. ¼, W. ½, SE. ¼.
Sec. 24: SW. ¼, S. ½ of SE. ¼.
Secs. 25 to 36 inclusive: All.
T. 30 S., R. 25 E.:
Sec. 29: W. ½ and SE. ¼ of SW. ¼.
Sec. 30: SW. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 31: All.
Sec. 32: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 33: W. ½ and SE. ¼ of SW. ¼.
T. 31 S., R. 20 E.:
Sec. 1: All.
Sec. 2: NW. ¼ and E. ½ of NE. ¼, NE. ¼ of SE. ¼.
Sec. 12: All.
Sec. 13: NE. ¼, E. ½ of NW. ¼, NW. ¼ and E. ½ of SE. ¼.
Sec. 24: NE. ¼ of NE. ¼.
T. 31 S., R. 21 E.:
Secs. 1 to 13 inclusive.
Sec. 14: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
Sec. 15: E. ½ and NW. ¼ of NE. ¼, SW. ¼ of NW. ¼, SW. ¼.
Sec. 16: NE. ¼, E. ½ and NW. ¼ of NW. ¼, SW. ¼ of SW. ¼.
Secs. 17 and 18: All.
Sec. 19: NW. ¼, NE. ¼ of SW. ¼, E. ½.
Secs. 20 to 28 inclusive: All.
Sec. 29: E. ½, NW. ¼, NE. ¼ of SW. ¼.
Sec. 30: NE. ¼ of NE. ¼.
Sec. 32: NE. ¼ of NE. ¼.
Sec. 33: E. ½, NW. ¼, NE. ¼ of SW. ¼.
Secs. 34, 35, and 36: All.
T. 31 S., R. 22 E.: All.
T. 31 S., R. 23 E.: All.
T. 31 S., R. 24 E.: All.
T. 31 S., R. 25 E.:
Sec. 3: SW. ¼ of SW. ¼.
Sec. 4: W. ½ and SE. ¼ of NE. ¼, NW. ¼, S. ½.
Secs. 5 to 9 inclusive: All.
Sec. 10: W. ½ of W. ½.
Sec. 15: NW. ¼ of NW. ¼.
Sec. 16: NE. ¼, W. ½, NW. ¼ of SE. ¼.

T. 31 S., R. 25 E.—Continued.
Secs. 17 and 18: All.
Sec. 19: NE. ¼, W. ½, W. ½ and NE. ¼ of SE. ¼.
Sec. 20: N. ½ of NE. ¼, NW. ¼.
Sec. 30: W. ½.
Sec. 31: W. ½ of NE. ¼, W. ½, SE. ¼.
Sec. 32: SW. ¼ of SW. ¼.
T. 32 S., R. 21 E.:
Secs. 1 and 2: All.
Sec. 3: E. ½, NW. ¼, NE. ¼ of SW. ¼.
Sec. 10: E. ½ and NW. ¼ of NE. ¼.
Secs. 11 and 12: All.
T. 32 S., R. 22 E.:
Secs. 1 to 17 inclusive: All.
Sec. 18: NE. ¼, NE. ¼ of NW. ¼, NE. ¼ of SE. ¼.
Sec. 20: NE. ¼, NE. ¼ of NW. ¼, NE. ¼ of SE. ¼.
Sec. 21: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
Secs. 22 to 26 inclusive: All.
Sec. 27: E. ½, NW. ¼, N. ½ of SW. ¼.
Sec. 28: E. ½ and NW. ¼ of NE. ¼.
Sec. 34: NE. ¼ of NE. ¼.
Sec. 35: N. ½, E. ½ and NW. ¼ of SE. ¼.
Sec. 36: All.
T. 32 S., R. 23 E.: All.
T. 32 S., R. 24 E.: All.
T. 32 S., R. 25 E.:
Sec. 5: W. ½ and SE. ¼ of NW. ¼, SW. ¼.
Secs. 6 and 7: All.
Sec. 8: W. ½.
Sec. 17: W. ½.
Secs. 18 and 19: All.
Sec. 20: NE. ¼ and W. ½ of NW. ¼, NW. ¼ of SW. ¼.
Sec. 30: NW. ¼ of NE. ¼, NW. ¼, NW. ¼ of SW. ¼.
Sec. 31: SW. ¼ of NW. ¼, W. ½ and SE. ¼ of SW. ¼.

[San Bernardino base and meridian.]

T. 12 N., R. 25 W.:
Sec. 32: E. ½, NW. ¼, NE. ¼ of SW. ¼.
Secs. 33 to 36, inclusive: All.
T. 12 N., R. 24 W.: All.
T. 12 N., R. 23 W.:
Sec. 28: W. ½, W. ½ of E. ½.
Secs. 29 to 32, inclusive: All.
Sec. 33: W. ½ and SE. ¼ of NE. ¼, NW. ¼, S. ½.
Sec. 34: W. ½ and SE. ¼ of SW. ¼.
T. 12 N., R. 22 W.:
Sec. 31: S. ½ of SE. ¼.
Sec. 32: S. ½ of NE. ¼, S. ½.
Sec. 33: NE. ¼, S. ½ of NW. ¼, S. ½.
Sec. 34: All.
T. 11 N., R. 25 W.:
Secs. 1, 2, and 3: All.
Sec. 4: N. ½, N. ½ of SE. ¼.
Sec. 5: NE. ¼ of NE. ¼.

T. 11 N., R. 25 W.—Continued.
Sec. 10: NE. ¼, NE. ¼ of NW. ¼.
Sec. 11: E. ½, NW. ¼, E. ½ and NW. ¼ of SW. ¼.
Sec. 12: All.
Sec. 13: NE. ¼, E. ½ and NW. ¼ of NW. ¼, E. ½ and NW. ¼ of SE. ¼.
Sec. 14: NE. ¼ of NE. ¼.
Sec. 24: SE. ¼ of SE. ¼.
Sec. 25: E. ½ of E. ½.
T. 11 N., R. 24 W.:
Secs. 1 to 18, inclusive: All.
Sec. 19: E. ½, E. ½ of NW. ¼, SW. ¼.
Secs. 20 to 30, inclusive: All.
Sec. 31: E. ½, NW. ¼, E. ½ of SW. ¼.
Secs. 32 to 36, inclusive: All.
T. 11 N., R. 23 W.:
Sec. 1: SE. ¼ of NE. ¼, S. ½ of SW. ¼, SE. ¼.
Sec. 2: SE. ¼ of SE. ¼.
Sec. 3: W. ½ of NE. ¼, W. ½, NW. ¼ of SE. ¼.
Secs. 4 to 9, inclusive: All.
Sec. 10: SW. ¼ of NE. ¼, NW. ¼ of NW. ¼, SW. ¼ and E. ½ of SW. ¼, SE. ¼.
Sec. 11: E. ½, E. ½ and SW. ¼ of NW. ¼, SW. ¼.
Secs. 12 to 36, inclusive: All.
T. 11 N., R. 22 W.:
Secs. 3, 4, and 5: All.
Sec. 6: E. ½, E. ½ and SW. ¼ of NW. ¼, SW. ¼.
Secs. 7 to 10, 15 to 22, 27 to 34, inclusive: All.

The following townships and parts of townships remain withdrawn pending completion of the geologic examination and classification thereof:

Lands withdrawn September 14, 1908, which remain withdrawn pending examination and classification.

[Mount Diablo base and meridian.]

T. 29 S., R. 17 E.: All.
T. 29 S., R. 18 E.: All.
T. 29 S., R. 19 E.:
Secs. 19 to 22, inclusive: All.
Sec. 23: W. ½ of W. ½.
Sec. 26: W. ½ of NW. ¼, SW. ¼.
Secs. 27 to 34, inclusive: All.
Sec. 35: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
Sec. 36: SW. ¼, SW. ¼ of SE. ¼.
T. 30 S., R. 17 E.: All.
T. 30 S., R. 18 E.: All.
T. 30 E., R. 19 E.: All.
T. 30 S., R. 20 E.:
Sec. 6: SW. ¼ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
Sec. 7: All.
Sec. 8: W. ½ and SE. ¼ of SW. ¼.
Sec. 17: SW. ¼ of NE. ¼, W. ½, W. ½ of SE. ¼.
Secs. 18, 19, and 20: All.
Sec. 21: SW. ¼ of SW. ¼.

T. 30 S., R. 20 E.—Continued.
- Sec. 27: SW. ¼ of SW. ¼.
- Sec. 28: SW. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 29 to 33, inclusive: All.
- Sec. 34: S. ½ of NE. ¼, W. ½, SE. ¼.
- Sec. 35: W. ½ and SE. ¼ of SW. ¼.

T. 31 S., R. 17 E.: All.
T. 31 S., R. 18 E.: All.
T. 31 S., R. 19 E.: All.
T. 31 S., R. 20 E.:
- Sec. 2: SW. ¼ of NE. ¼, W. ½, W. ½ and SE. ¼ of SE. ¼.
- Secs. 3 to 11, inclusive: All.
- Sec. 13: W. ½ of NW. ¼, SW. ¼, SW. ¼ of SE. ¼.
- Secs. 14 to 23, inclusive: All.
- Sec. 24: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 25 to 36, inclusive: All.

T. 31 S., R. 21 E.:
- Sec. 19: W. ½ and SE. ¼ of SW. ¼.
- Sec. 29: W. ½ and SE. ¼ of SW. ¼.
- Sec. 30: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Sec. 31: All.
- Sec. 32: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Sec 33: W. ½ and SE. ¼ of SW. ¼.

T. 32 S., R. 17 E.: All.
T. 32 S., R. 18 E.: All.
T. 32 S., R. 19 E.: All.
T. 32 S., R. 20 E.: All.
T. 32 S., R. 21 E.:
- Sec. 3: W. ½ and SE. ¼ of SW. ¼.
- Secs. 4 to 9, inclusive: All.
- Sec. 10: SW. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 13 to 36, inclusive: All.

T. 32 S., R. 22 E.:
- Sec. 18: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE ½.
- Sec. 19: All.
- Sec. 20: W. ½ and SE. ¼ of NW. ¼, SW. ¼, W. ½ and SE. ¼ of SE. ¼.
- Sec. 21: SW. ¼ of SW. ¼.
- Sec. 27: S. ½ of SW. ¼.
- Sec. 28: SW. ¼ of NE. ¼, W. ½, SE. ¼.
- Secs. 29 to 33, inclusive: All.
- Sec. 34: W. ½ and SE. ¼ of NE. ¼, W. ½, SE. ¼.
- Sec. 35: SW. ¼, SW. ¼ of SE. ¼.

[San Bernardino base and meridian.]

T. 12 N., R. 27 W.: All.
T. 12 N., R. 26 W.: All.
T. 12 N., R. 25 W.:
- Sec. 31: All.
- Sec. 32: W. ½ and SE. ¼ of SW. ¼.

T. 12 N., R. 22 W.:
- Secs. 25, 26, 35, and 36: All.

T. 11 N., R. 27 W.: All.
T. 11 N., R. 26 W.: All.

T. 11 N., R. 25 W.:

Sec. 4: SW. $\frac{1}{4}$, S. $\frac{1}{2}$ of SE. $\frac{1}{4}$.
Sec. 5: W. $\frac{1}{2}$ and SE. $\frac{1}{4}$ of NE. $\frac{1}{4}$, W. $\frac{1}{2}$, SE. $\frac{1}{4}$.
Secs. 6 to 9, inclusive: All.
Sec. 10: W. $\frac{1}{2}$ and SE. $\frac{1}{4}$ of NW. $\frac{1}{4}$, S. $\frac{1}{2}$.
Sec. 11: SW. $\frac{1}{4}$ of SW $\frac{1}{4}$.
Sec. 13: SW. $\frac{1}{4}$ of NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of SE. $\frac{1}{4}$.
Sec. 14: W. $\frac{1}{2}$ and SE. $\frac{1}{4}$ of NE. $\frac{1}{4}$, W. $\frac{1}{2}$, SE. $\frac{1}{4}$.
Secs. 15 to 23, inclusive: All.
Sec. 24: NE. $\frac{1}{4}$, W. $\frac{1}{2}$, NE. $\frac{1}{4}$ and W. $\frac{1}{2}$ of SE. $\frac{1}{4}$.
Sec. 25: W. $\frac{1}{2}$, W. $\frac{1}{2}$ of E. $\frac{1}{2}$.
Secs. 26 to 36, inclusive: All.

T. 11 N., R. 24 W.:

Sec. 19: W. $\frac{1}{2}$ of NW. $\frac{1}{4}$.
Sec 31: W. $\frac{1}{2}$ of SW. $\frac{1}{4}$.

T. 11 N., R. 22 W.:

Secs. 1, 2, 11, 12, 13, 14, 23, 24, 25, 26, 35, and 36: All.

GEOLOGY.

GENERAL STATEMENT.

The main and subsidiary ranges of the McKittrick-Sunset region consist almost wholly of sedimentary rocks which have been uplifted, folded, and faulted by the intense forces producing the mountains and depressions of this portion of California. Through the subsequent dissection of these upturned and folded sediments, by stream and climatic agencies, the succession of beds can be studied. Thus there have been differentiated the following formations, stated in the order of their age, from earliest to latest. After each formation name appears the name of the time division to which it belongs:

Franciscan formation (Jurassic?).
Knoxville-Chico rocks (Cretaceous).
Tejon formation (Eocene).
Oligocene (?).
Vaqueros sandstone (lower Miocene).
Monterey shale (lower middle Miocene).
Santa Margarita (?) formation (upper middle Miocene).
McKittrick formation (upper Miocene to Pleistocene). Represents the Jacalitos, Etchegoin, and Tulare formations of the Coalinga district.
Fan deposits and stream terraces (Pleistocene to Recent).

With the exception of certain intrusive and metamorphic rocks in the Franciscan, and of two areas of basalt associated with the Miocene beds, these formations consist wholly of marine and fresh-water sediments. The distribution of these indicates that during the region's earlier geologic history sedimentation took place in the sea or its estuaries, but that with the inception of the Pliocene epoch, brackish and fresh water conditions prevailed.

While the problems arising from the study of the region are many and intricate, only those conditions which control the accumulation and availability of the petroleum products can be fully discussed in a preliminary report of this nature.

It has been found that the Franciscan, Knoxville, and Chico formations are not oil bearing, and that the Tejon formation (Eocene), while possibly affording reservoirs for oil, is not an important source thereof, as it has been shown to be in the Coalinga region. The Monterey and Santa Margarita (?) formations, however, have proved to be the most important sources of petroleum; from these the product has passed downward into the more porous sands and gravels of the underlying Vaqueros (lower Miocene) and upward into the interbedded lenses in the Santa Margarita (?) and also into the deposits of the McKittrick formation, unconformably overlying the Santa Margarita (?) and Monterey formations, where it has largely been retained until tapped by wells. At certain points, however, through denudation or structural disturbance, petroleum products, usually asphaltic, have become associated with the upper part of the McKittrick formation, and even in small quantities with the more recent deposits.

Facts relative to the structural conditions and the physical character of the formations are most important in a discussion of any California oil field, and in none more than in those under consideration, since this region is one of geologic instability.

The following chapters aim to give, as briefly as possible, a statement of these conditions in the McKittrick-Sunset region.

STRATIGRAPHY.

NON OIL-BEARING SERIES.

FRANCISCAN FORMATION (JURASSIC?).

GENERAL DESCRIPTION.

In various portions of the Coast Ranges there exists a complex of igneous and pre-Cretaceous sedimentary rocks, for the larger part intricately flexed, fractured, and faulted, which has been called "the Franciscan formation." Secondary silicification and metamorphism have converted some of the original sandstones into quartzites, shales into slaty rocks and jaspers, limestones into marbles, and have often produced glaucophane, mica, and actinolite schists. Serpentine occurs associated with the Franciscan rocks both in irregular masses and as dikelike bodies.

While certain less-altered facies of the Franciscan sedimentaries resemble the shales and sandstones of the Knoxville, the ensemble of the Franciscan is distinctly unlike that of any later series of rocks in the region. Topographically, the Franciscan has a craggy but in general broadly rounded relief, which strongly contrasts with the parallel strike ridges developed in the post-Franciscan sediments. Drainage lines are developed regularly and show but slightly that influence of varying rock hardness which so often affects the courses of channels draining areas of later sedimentaries.

The formation contains no diagnostic fossils, so far as known, but upon such evidence as it has been possible to obtain in this region or elsewhere, it is placed within the Jurassic.

ANTELOPE VALLEY AREAS.

The Franciscan formation upon either side of Antelope Valley consists of several elongated areas and a number of small irregular bodies of rocks typical of this formation. Perhaps the most striking of these extends along the southern base of Orchard Peak, where its vivid green and purplish color, due to the presence of serpentine, is in strong contrast with the dull gray and brown of the surrounding Cretaceous shales. At its eastern end near Aido Spring this narrow body consists largely of schists and reddish jasper associated with dark-green metamorphic sandstone. In the direction of Polonio Pass, toward the west, this Franciscan area widens somewhat and serpentine predominates.

A second important body of Franciscan rocks extends along the southwest side of Antelope Valley from sec. 31, T. 25 S., R. 17 E., to sec. 16, T. 26 S., R. 17 E., where it is lost beneath the gravels of Barril Valley. This mass, which is mostly serpentine, with a minor amount of sandstone, is a narrow wedge which has been faulted up diagonally across the strike of the later sediments. A similar wedge of serpentine has been forced up between the Miocene sandstone and Cretaceous shales north and east of McGovern's ranch, and at its northern extremity in sec. 21 occurs a remarkable organic limestone containing fragments of chert and greenstones, but apparently interbedded with the latter.

Another small sheared mass of serpentine lies within the San Andreas fault zone near Carter's ranch. Smaller Franciscan masses lie in secs. 27, 28, 34, and 35 of T. 26 S., R. 17 E., and at that in the canyon of Franciscan Creek (sec. 35) the following succession of rocks has been observed, going downstream:

(*a*) A zone of dark-blue clay, resembling vein gouge; this undoubtedly is due to faulting along the contact with a later series which lies to the south.
(*b*) Blue-green shale—a transition phase of the more siliceous chert and jasper.
(*c*) Green chert—typical chert of the Franciscan.
(*d*) Green sandstone, much sheared.
(*e*) Red and green chert interbedded.
(*f*) Red and green spotted sandstone; this is apparently made up of bits of the adjoining bed and also contains serpentine or greenstone grains, but does not resemble the usual type of sandstone of the Franciscan formation. Its composition indicates a later age than that of the adjacent chert, or than some of the serpentine, at least.
(*g*) Green sandstone—a portion of the above.

All these rocks are much sheared. The organic limestone and the red and green spotted sandstones described above are unusual occurrences, and may mark a later phase of the Franciscan sedimentation than has been heretofore observed.

OTHER AREAS.

In the SE. ¼ sec. 30, T. 27 S., R. 18 E., is an interesting area of Franciscan. While mostly serpentinous, there is at the southern end a patch of light-blue breccia which appears to be a much crushed glaucophane schist; at the northern end of the exposure is a resistant mass of dark-green, fine-grained diorite (diabase?), unlike any rock found elsewhere in this region.

The most southerly area of Franciscan rocks that has yet been noted in the Temblor Range lies mostly in sec. 3, T. 28 S., R. 18 E., where crushed reddish jaspers and serpentine have been faulted into Cretaceous shales and sandstones.

The unusual structural relations between these several Franciscan areas and the neighboring rocks will be discussed under the heading "Structure" (p. 92).

These several surficially disconnected bodies of Franciscan rocks are undoubtedly portions of the old core of the range. This core has suffered so much deformation and at places has been so deeply buried beneath the later sediments that its original continuous character is not obvious; yet, from conditions in other portions of the Coast Ranges, it is safe to assume that the Franciscan forms the basement upon which a large part of the Cretaceous and later sediments have been deposited.

IMPORTANCE WITH RELATION TO PETROLEUM.

So far as known the Franciscan rocks of the Coast Ranges yield no indications of petroleum, and they are important only as a part of the basement complex upon which the younger oil-bearing formations are laid down. The presence of Franciscan rocks at any particular point should alone be sufficient evidence to condemn it for purposes of oil exploitation.

KNOXVILLE-CHICO ROCKS (CRETACEOUS).

GENERAL DESCRIPTION.

The Knoxville-Chico rocks, the next younger in age than the Franciscan, are those deposited unconformably upon it in the ocean during Cretaceous time. These consist of a great thickness of firm, dark-colored shales and sandstones with some conglomerates. They are exposed in four groups of one or more areas each in the McKittrick-Sunset region, and include sediments of both Knoxville and Chico age. A separation of these two formations is not essential to an understanding of the oil conditions in the region, and has not been attempted, although lithologically the two formations are roughly separable. The Knoxville consists in general of 4,000 to 6,000 feet of black to greenish-brown shales, with minor amounts of dark-green nonnodular sandstone. Some conglomerate occurs within the Knoxville, but it is discontinuous and can not be said to mark a widespread time break. The upper 3,000 to 5,000 feet of the Cretaceous consists of the Chico formation (sandstones with a minor amount of shale). These sandstones are yellowish, massive, and usually contain layers of hard rounded dark-brown nodules, which, more than anything else, serve to differentiate the Chico from other sandstones.

A consideration of the general character of the Cretaceous in the McKittrick-Sunset region leads to the conclusion that the sediments were all deposited under nearly uniform conditions, although toward the close of the Cretaceous either the seas became shallower or the land masses from which the coarser sandstones of the Chico were derived suffered an uplift. Local shallow water conditions are also indicated by the conglomerate zones. Deformational influences appear to have been active before the initiation of the Eocene, and at some point erosion progressed far enough during the uplift following the laying down of the Chico for the complete removal of several thousand feet of sandstone and shale belonging to this formation, before the Eocene or later sediments were deposited, or else the Knoxville overlain by the Eocene was above water in Chico time.

Lithologically, the most characteristic feature of the earlier Cretaceous sediments is their olive-green to greenish-brown color, and of the later sandstones their nodularity.

ORCHARD PEAK AND DEVILS DEN AREA.

The Orchard Peak and Devils Den area lies almost entirely within T. 25 S., R. 17 E., and T. 25 S., R. 18 E., and comprises the high range of mountains forming the southernmost extremity of the Diablo Range as well as some of the lower country in the Barton Hills. Broadly speaking, the shales of the Knoxville formation predominate, and their dark color gives to the region a somber appearance, which is emphasized by its aridity and barrenness of vegetation.

The best section of the Knoxville is that exposed upon the steep scarp which forms the southern face of Orchard Peak, where the beds dip monoclinally northward at angles varying from 30° to 80°.

At the base of this scarp and just above the margin of Antelope Valley are coarse gritty sandstones containing many unrecognizable fossil shell bits. These are overlain by dark greenish shales and spheroidally weathered sandstones, with which are interbedded grayish quartzites and shales at elevations of 1,700, 2,100, and 2,250 feet. Above these are dark grayish nodular shales and moderately hard sandstone beds. The top of the ridge, at an elevation of about 3,000 feet, is a heavily bedded, dark-green resistant sandstone which gives the summit an unusually precipitous appearance.

In the subsidiary hills known as Sawtooth Ridge, south of the main scarp, the Cretaceous sandstones carry hard dark-brown concretionary layers, which resist weathering and give the ridge a pinnacled topography. Some of these layers are made up of finely comminuted shell fragments similar to those noted at the foot of the main scarp.

The monoclinal structure in the Cretaceous persists with slight modifications from Orchard Peak northeastward to McLure Valley, and the character of the sediments is the same as far as a point near the margin of the valley, where the sandstones are more massive and nodular as well as lighter in color. Chico fossils have been found near Spreckels well, in association with interbedded sandstone and shales.

At the extremity of the high spur which extends southeastward from Orchard Peak, several well-defined conglomerate beds have a nearly vertical attitude. They were traced about three-fourths of a mile and may locally mark the line between the Chico and Knoxville formation.

Two isolated Cretaceous areas lie in the Barton Hills, and both have been definitely determined as of Knoxville age, through the presence of well-preserved *Belemnites* and *Aucella*. The more important of these areas is that extending east and west through secs. 19, 20, and 21 of T. 25 S., R. 18 E., and known locally as Devils Den. The greenish-gray soft shales which are exposed here have been so sheared and crushed that their structure is almost lost. Just at the Devils Den they have been locally hardened by saline waters which exude irregularly from the shale, and differential erosion has produced an intricate system of crags and canyons in miniature. The southern margin of this Knoxville area is in contact with Tejon (Eocene) sandstone and conglomerate, which are overturned against it.

The other area of Cretaceous extends north and south along the crest of the ridge terminating in Point of Rocks, and consists wholly of a similar dark bluish to green soft shale, with some beds of dark-colored sandstone. The series dips to the eastward and owes its presence at the surface to a fault along the west side of the area. Directly over these Knoxville beds lies the Tejon formation. Observed structural conditions alone do not explain the attitude of the Barton Hills Knoxville with reference to the Orchard Peak mass. Not only must there have been faulting immediately following the Chico intense enough to bring the Knoxville up against the sandstones of the Chico, but the Eocene must have been deposited after this relation had been established, and after erosion had removed the overlying Chico, since the Eocene lies directly upon the Knoxville.

AREAS NEAR McGOVERN'S RANCH.

Several small elongated blocks of Cretaceous exist in the vicinity of McGovern's ranch in the central part of T. 26 S., R. 17 E., and these consist in general of typical dark-green, somewhat nodular shales and firm sandstones, considerably faulted and flexed. The exposures along the road 1 mile south of McGovern Gap are characteristic. The investigation of these areas was too cursory to determine whether they are Knoxville or Chico in age.

BITTERWATER CREEK AREAS.

The smaller of the Bitterwater Creek areas lies mostly in sec. 28, T. 26 S., R. 18 E., and probably is a part of the Orchard Peak mass, from which it is separated by the alluvial material filling Antelope Valley. The beds are mostly of dark-colored, evenly bedded sandstone, separated by thinner blackish and rusty shales. The beds have been faulted up against the overlying Santa Margarita (?) formation.

Owing to the denudation of a great anticlinal structure in the shales of the Santa Margarita (?) formation between Barril Valley and Bitterwater Creek, there is exposed an elongated mass of the underlying Cretaceous, which, while conforming in general with the structure of which it is a part, yet shows many minor folds that probably did not affect the incumbent beds at all. This area presents no unusual features; the rocks are dull-green or brown sandy shales and brownish-green plainly-bedded sandstones. The area has not been traced south of Bitterwater Creek.

CEDAR CANYON AND SALT CREEK AREA.

A narrow elongated Cretaceous area occupies the core of the Temblor Range from Bitterwater Creek southeastward to Temblor ranch, and is important, not only because of its size, but because it was the rigid floor upon which the later oil-bearing sediments have been deposited and against which they have been folded. Lithologically the area is uniform, exposures of typical shale and sandstone in Cedar Canyon, at its north end, resembling closely those on Carneros or Salt Creek near Temblor ranch. In this area of Cretaceous rise the best springs of the whole Temblor Range, both in quantity and quality of the water produced. Nowhere in the whole area have fossils been found, but there is no doubt of the Cretaceous age of the series. This is the most southerly exposure of Cretaceous in the Temblor Range, although similar beds occur on both flanks of the Mount Pinos Range at the south end of the San Joaquin Valley.

IMPORTANCE WITH RELATION TO PETROLEUM.

So far as observed in the McKittrick-Sunset region, the Cretaceous rocks are not oil bearing and are important only as forming a platform on which the younger petroliferous formations rest. Much money has been uselessly expended in searching for petroleum in the

Chico, over $70,000 having been thus spent at one point near Devils Den. The presence of Cretaceous rocks at any particular locality, unless they contain a considerable amount of organic shale, should of itself be sufficient evidence to discourage prospecting for petroleum at that point.

TEJON FORMATION (EOCENE).

GENERAL STATEMENT.

The Tejon formation, named from old Fort Tejon in Grapevine Canyon, where it was first described and its fauna first studied, occurs at several places in the McKittrick-Sunset region. It consists usually of rather massive, tawny sandstone, nodular in places, which is easily differentiated from the overlying Vaqueros, but often very closely resembles the sandstones of the Chico. The Tejon is clearly unconformable upon the Knoxville, but its relation to the Chico approaches conformity, a condition which, combined with the close resemblance between the Chico and the Tejon, makes separation difficult.

The extent and continuity of the basin in which the Tejon was deposited is not now discernible; long-continued faulting and the overlap of later sediments have effectually obscured them. Two groups of areas, one comprising most of the ridge between Devils Den and Point of Rocks, and the other two elongated areas between Bitterwater Creek and Temblor ranch, provide the only evidence in this region of what must once have been a widespread deposit.

POINT OF ROCKS AREA.

The largest of the three tracts comprised in the Point of Rocks area consists almost wholly of tawny and light grayish sandstone with a minor amount of sandy shale. The basal beds of the Tejon here consist of a rather coarse greenish to brown gritty sandstone, from which, at several points, characteristic Tejon fossils were obtained.

An unconformity with the underlying Cretaceous is proved by the abundant basal conglomerate of Cretaceous sandstone, quartzite, diabase, and calcareous shale pebbles associated with the fossil reef. The formation is best exposed at Point of Rocks, where the beds dip about 20° NE. The succession there is about as follows, beginning with the uppermost:

Section of Tejon formation at Point of Rocks.

	Feet.
Nodular and cavernous sandstones	550
Massive buff sandstones	350
Nodular sandstones	250
Massive cavernous sandstones	200
Nodular and less conspicuous sandstones	750
Basal grit and sandstones (with fossils)	200
	2,300

The apparent thickening in the Tejon between this place and the northern part of the area is due both to the development of a broad syncline in the northwest part of the area and to faulting which repeats some of the series. It is considered, therefore, that an average thickness of 2,300 feet for the Tejon in this region is not far from the fact.

In contrast with the Eocene of the Coalinga region, the Eocene of Point of Rocks contains only a very minor amount of blackish clay shale, and, so far as observed, none of the light-colored diatomaceous shales which are so important to the oil production in the Coalinga district.

The massive cavernous sandstones referred to in the above table are characteristic of the Tejon. Such are the prominent, isolated croppings at Point of Rocks, long a stronghold of warring desert Indian tribes, which used the natural grottoes and an artificial depression in the sandstone buttes as places of concealment and water storage during siege.

McDONALD'S RANCH AREA.

Through denudation of a northwest-southeast anticline, there have been exposed beds of brownish sandstone, which are tentatively referred to the Tejon, although no supporting paleontologic evidence is available. The best exposure of these sandstones is that along the road just northeast of McDonald's ranch, where they form the regularly arching anticlinal axis of the structure referred to above. Lavender to reddish-brown discolorations in the sandstone at a point northwest of the ranch are among the noticeable characteristics of the supposed Tejon here.

MEDIA AGUA CREEK AND CARNEROS SPRING AREA.

The northwestern end of a belt of sandstones of the Tejon formation is exposed just at the mouth of Cedar Canyon as a massive, somewhat cavernous, yellow sandstone, and retains this character to the region immediately north of the Temblor ranch. A particularly picturesque exposure of the Tejon occurs at Carneros Spring, where the coarse, heavy-bedded, yellowish-brown concretionary sandstone beds, dipping about 30° NE., rise in prominent pinnacles over a hundred feet in height. Surface slopes coincident with bedding planes are also one of the noticeable features at this spring. In general the Tejon is thinner bedded and contains more shale toward the base and is more concretionary toward the top. Owing to the several folds in the Tejon on the flanks of the Temblor Range south and west of Carneros Springs, the apparent thickness of the Tejon is much greater than the actual thickness. A conservative estimate of the thickness of the Tejon in the region west of Carneros Springs is 2,300 feet, the same as that in the region of Devils Den.

IMPORTANCE WITH RELATION TO PETROLEUM.

No petroleum has so far been obtained from the Tejon in the McKittrick-Sunset district, but the pinkish and other discolorations found at certain outcrops are believed by some to be indicative of oil.

OLIGOCENE(?) ROCKS.

DISTRIBUTION AND CHARACTER.

In only two restricted portions of the whole region have rocks of possible Oligocene age been found. The more important of these areas is in the Devils Den region north and southwest of Wagonwheel Mountain. Here a series of massive light-gray and buff nonnodular sandstones, inclosing a fossiliferous reef, are overlain by yellowish and cream-colored calcareous shales. The latter grade upward into gypsiferous gray shales and sandstones that immediately underlie the "reef beds" of the Vaqueros, being separated from the latter by a layer of small, black, slaty pebbles. A section was measured across the series, which dips northeastward, and the following succession of beds from the top downward was found:

Section of Oligocene (?) rocks southwest of Wagonwheel Mountain.

	Feet.
1a. Soft shales and sands with yellowish calcareous layers	200
1b. Gray coarse sandstone with small and large pebbles of quartz and a hard, black metamorphic, apparently a slate, cemented by calcareous material.	75
2. Grayish soft shale, poor outcrops, weathering into a smooth, mouse-colored soil	290
3. Fine-grained gray sandstone, with alternating yellow calcareous layers; outcrops fragmental	115
4. Shale and sandstone bits and fragments; poor outcrops. Some of this sandstone is light gray and firm in texture with quite abundant grains and patches of pyrite	520
5. Gypsiferous sandstone and shale	40
6. Gypsum and sandstone, the former as irregular veinlets	10
7. Grayish to chocolate-colored clay shales with gypsum	125
8. Grayish shaly material with yellow nodular layers	90
9. Pale lavender clayey shale, weathering almost pure white. Not of organic origin	7
10. Grayish and cream-colored shale	18
11. Yellow fine-grained calcareous shale, thin calcite veinlets	10
12. White to cream-colored shale, not well exposed	75
13. Soft gray fine sandy soil (no exposures)	120
14. Yellowish calcareous shale with a hard yellow layer at the top	20
15. Grayish massive light-gray to buff nonnodular sandstone, inclosing fossiliferous calcareous reef	105
	1,820

FOSSILS AND AGE.

The fossils found in the basal beds of this series are as follows:

Lima sp. indet.
Petricola n. sp.
Phacoides n. sp. aff. californica Conrad.
Thyasira n. sp. aff. bisecta Conrad.
Fusus sp. indet.

In a light-brown shale beneath a bluish diatomaceous shale in the NW. ¼ sec. 1, T. 26 S., R. 18 E., the following fossils were collected:

Pecten peckhami Gabb.
Terebratalia n. sp.
Fish scale.
Shark's tooth.

With the exception of *Pecten peckhami* Gabb, which ranges from the Eocene or Oligocene to the Miocene, the stratigraphic position of none of the fossils mentioned is known. The stratigraphic affinities of the beds are with the Eocene, and while the paleontologic are with the lower Miocene, they are possibly to be correlated with the white diatomaceous shale tentatively mapped with the Tejon in the Coalinga district, and may possibly be of Oligocene age.

AREA NEAR BARTON'S.

The smaller isolated area of similar sands and shale lies in the Barton Hills, about 1½ miles north of the former locality and in the same relative position beneath the "reef beds" of the Vaqueros sandstone. The strike of the beds here and their lithology show that they are very evidently a part of the Oligocene(?) rocks.

RELATION TO OIL.

Some of the shales in the area near Wagonwheel Mountain are partly organic in origin and may have been the source of the oil which has been found in the basal Miocene beds of the Barton Hills. No deposits of petroleum or surficial evidence of its occurrence in the formation are known anywhere.

OIL-BEARING SERIES.

GEOLOGIC HISTORY.

Most of the petroleum in the McKittrick-Sunset region is believed to have originated in the post-Eocene sediments; also, since the members of this series in general resemble one another physically and are quite unlike either the Tejon or the Knoxville and Chico beds, it is natural to consider them first as a unit.

Under just what conditions the oil-bearing series were deposited it is now difficult to say. The successive uplifts and depressions of the old land masses and the long-continued, complicated faulting and folding to which all the sedimentary series have been subjected have greatly obscured the original relations of the post-Eocene sediments. It is unsafe, therefore, to make generalizations as to their thickness, occurrence, and interrelations and apply them alike to the several areas in the region.

It is evident, however, that Eocene deposition was terminated by an uplift which placed much of the Coast Range region, including the Temblor Range, above sea level during the Oligocene, although at the same time sedimentation was probably in progress to the eastward throughout the San Joaquin Valley depression. Miocene sedimentation in the McKittrick-Sunset region was introduced by a uniform lowering of the Temblor Range and the region to the west to a depth sufficient to permit deposition over practically the entire surface. It is probable that the south end of the Diablo Range and most of the Mount Pinos Range were above sea level during this time. Sandstone from a few feet to many hundreds of feet in thickness was first laid down in the region of subsidence, and then followed a period during which diatoms flourished in the waters, and the great deposits of diatomaceous shale of the Monterey and Santa Margarita(?) formations were laid down. During the Santa Margarita(?) epoch, and to a less extent during the Monterey, the quiescent periods of diatom deposition were interrupted by locally turbulent conditions in which coarse granitic conglomerates were carried into the sea and deposited as lenses, which now are intercalated with the diatomaceous shale.

Following the Santa Margarita(?) epoch came a period of uplift and erosion, then another subsidence during which the McKittrick formation was laid down unconformably upon the eroded surface of the older formations. Probably alternating fresh, brackish, and marine conditions followed the marine conditions existing during the earlier part (Jacalitos) of the McKittrick, and it is probable, also, that some of the sediments in the later part (Tulare) may be of continental origin. A period of uplift and deformation of strata, probably in the early Quaternary, began the present geologic cycle.

VAQUEROS SANDSTONE (LOWER MIOCENE).

GENERAL STATEMENT.

The Vaqueros sandstone has a wide extent throughout the McKittrick-Sunset oil region, and is of such importance in connection with the problem of oil accumulation and storage that it will be dealt with in considerable detail. The unconformity between the sandstone of the Tejon (Eocene) and the lower Miocene marks an important hiatus in the succession of beds. Although at many places throughout the region this unconformity is not noticeable, it nevertheless represents a great time interval, during which much of the Coast Range region was above sea level. In the Devils Den district at least a part of this interval was occupied by the deposition of the Oligocene(?) rocks.

Unlike the simple relations between the Vaqueros sandstone and the beds underlying and overlying it throughout much of the Coalinga district, the relation of the Vaqueros in the McKittrick-Sunset region to the adjacent strata is complex. The various formations have been so involved by complicated structural agencies that they do not dip uniformly toward the San Joaquin Valley, nor lie in a single well-defined belt of sediments skirting the flanks of the Temblor Range. Despite this, the Vaqueros in its more intimate characteristics, as of paleontology, lithology, color, thickness, etc., is quite uniform. It consists nearly everywhere of beds of tawny to brownish, medium-grained sandstones, generally containing many fossils, and nearly everywhere calcareous. The beds are almost always resistant, and hence produce a characteristic reef topography which alone is usually sufficient to distinguish the beds from any others in the region.

In some parts of the region the beds making up the Vaqueros contain two calcareous beds known as "reef beds," separated often by softer somewhat shaly sandstone. Where this double character of the Vaqueros is apparent, as near Carneros Spring, the terms "upper reef" and "lower reef" have been used. The Vaqueros beds are for the most part uniformly arenaceous, but near Annette and upon the southwest side of the Carrizo Plain the sands evidently in part grade into light-colored shales closely resembling the Monterey. The minimum thickness of the Vaqueros sandstone in the McKittrick-Sunset region is probably 60 feet and the maximum about 2,400 feet.

The Vaqueros occurs in numerous related areas, none of them of great size, throughout the McKittrick-Sunset region. On account of their small size they will be described in four districts of several areas each, and one separate area, as follows:

Devils Den district, including about ten areas; the district between Antelope Valley and Bitterwater Creek, including eight or more areas; the district extending southeastward from Bitterwater Creek to a line drawn approximately along Salt Creek and from near its head arbitrarily westward through Wolfort's ranch to the edge of Carrizo Plain, this third district containing three elongated discontinuous areas; and a fourth district, including all the areas of the Vaqueros from Salt Creek southeastward to the southern limit of the region mapped, except the area of Vaqueros lying upon the southwest side of Carrizo Plain, which will be separately treated. This classification of Vaqueros areas is largely artificial, but is necessary in the consideration of such an extensive region.

DEVILS DEN DISTRICT.

Area south of Barton's.—The Vaqueros south of Barton's consists of between 60 and 150 feet of calcareous light-colored sandstone, sometimes pebbly and containing many fossils throughout its length. In places there are two well-defined fossil beds, each about 20 feet thick and 40 or more feet apart. These show slight local variations in thickness, but otherwise are unusually uniform. Characteristic Vaqueros fossils have been collected in this vicinity, most of them from the débris upon the south side of the ridge in sec. 23, known locally as Mastodon Hill.

At the extreme southeast end of this area the Vaqueros sandstone passes beneath alluvial material of much later age, and just at the junction of the two formations there is a tar spring, which flows with about one-fourth inch of strong sulphur water and turns silver coins black almost instantly upon immersion. Small blebs of black oil accompany the water and a thin iridescent film of oil covers the surface. Gas bubbles almost continuously from the mud in the bottom of the spring, which is 4 or 5 feet in diameter. The spring apparently rises in the reef bed and has deposited asphaltum in the reef at several places adjacent to the present orifice. Although the water tastes strongly acid and has an unpleasant odor, it does not seem to be deadly, since large numbers of birds and animals make use of it.

Wagonwheel Mountain area.—The indurated fossiliferous sandstones and the underlying softer beds of this area dip about 30° NE. and extend along the northeast flank of the group of hills, of which Wagonwheel Mountain is the most prominent point. The lowest beds, which may be transitional into the Oligocene(?) to the southwest (see section of Oligocene(?) rocks on p. 40), is a dark gypsiferous shale containing yellow calcareous concretions. About 50 feet below the hard reef these lower beds become sandy and represent the beginning of the change in sedimentation which later produced the "reef beds." The "reef bed" itself is about 60 feet thick and is abundantly supplied with fossils, which weather from the matrix and accumulate in great numbers in the débris about the foot of the steeper faces of the reef. The "reef bed" dips northeastward directly beneath the unconsolidated gravels of the valley, with no croppings of the overlying white shales which are so well exposed in the Devils Den area.

Area south of Dagany Gap.—A slender, elongated S-shaped area of dark-colored fossiliferous sandstone is exposed here through the denudation of an anticline plunging southeast. The bed is between 15 and 25 feet thick and is much less conspicuous than the Vaqueros usually is. It undoubtedly represents a northward continuation of the more prominent beds in the vicinity of Barton's.

Other areas.—Just north of Devils Den itself is a rather thin bed of yellowish fossiliferous sandstone standing nearly vertical and very evidently faulted into the shales of the Knoxville and the Eocene sandstones that surround it. This area is unimportant except in showing the intense structural modification to which the lower Miocene has in places been subjected. Considerable variation in thickness, apparently due to faulting, has been noted in this particular area. Characteristic Vaqueros fossils were found not far from the little cabin in the NW. ¼ sec. 21, T. 25 S., R. 18 E.

South of Devils Den are several isolated areas of sandstone and sandy shales of the Vaqueros which lie nearly flat upon the Eocene. They are fossiliferous, but unimportant from an economic standpoint, since they are only remnants of what must once have been an extensive area lying unconformably upon the Tejon.

It is evident from the relations of these several areas comprised within the Devils Den district that the Vaqueros formation overlaps unconformably not only both the Eocene and the Cretaceous, but the Oligocene (?).

DISTRICT BETWEEN ANTELOPE VALLEY AND BITTERWATER CREEK.

General statement.—The Vaqueros area southwest of Antelope Valley is intensely disturbed. Close and overturned folding, probably accompanied by faulting parallel to the axial lines and followed by cross faulting in which structures already developed were horizontally displaced, have rendered the problem of formational classification difficult in this region. Indeed, in secs. 25, 26, 35, and 36 of T. 26 S., R. 17 E., the structural conditions are so obscure that separation of the formations has not been attempted. Aside from this vicinity, the Vaqueros is a fairly well defined light-grayish massive sandstone and occupies two elongated areas, one extending from west of Polonio Pass southeastward past McGovern's ranch to the ridge south of Franciscan Creek and the other from the south slope of the same ridge southeastward through Packwood ranch nearly to Bitterwater Creek.

McGovern's ranch area.—The northern end of the area near McGovern's ranch is a broad syncline of massive sandstones and sandy shales, which has been truncated by a narrow block of serpentine faulted up against its eastern end. A section was carefully measured across the south arm of this syncline, and the following succession noted:

Section of Vaqueros sandstone near McGovern's ranch.

	Feet.
Light-colored sandstone and shale	650
Sandy shale, darker than inclosing sandstone	405
Massive cavernous buff, uniform sandstone	650
Dark-colored well-defined bed of shale	80
Massive brownish yellow sandstone	570
	2,355

The following fossils fixing the Vaqueros (lower Miocene) age of the formation have been found in the lower standstones here:

Panopea aff. estrellana Conrad.
Pecten estrellanus Conrad.
Turritella ocoyana Conrad.

Although displacements are common at the base and within the series elsewhere, along the line of the above section no faulting is apparent. Hence the determined thickness of 2,355 feet is not far from correct.

South of the Annette–McGovern Gap road the Vaqueros has been thrown into an anticline, against and through which have been forced blocks and small irregular masses of older rocks. It is, therefore, difficult to state either the succession or the thickness of the Vaqueros beds. In general, they consist of rather soft grayish to buff, sometimes cavernous sandstones, ranging in grain from fine to coarse and conglomeratic, as in sec. 27, T. 26 S., R. 17 E., just south of Imfled's ranch houses, where dark chert and quartzitic pebbles occur. The following Vaqueros fossils have been found in the last-mentioned vicinity:

Pecten bowersi Arnold.
Pecten estrellanus Conrad.
Phacoides sanctæcrucis Arnold.

On the southwest side of this portion of the area the relation to the Cretaceous sandstones is apparently an unconformity where no faults exist. Where the gravels and clays of the upper part (Tulare) of the McKittrick formation overlap upon the southern part of the area there is a striking unconformity in the attitude of the two formations. Along the northeastern flank of the Vaqueros there are evidently beds transitional between the Vaqueros sandstone and the Monterey shale.

Packwood ranch area.—This area, while undoubtedly a southeastern continuation of that just described, is more simple structurally, and for the present purposes may be defined as an anticline which plunges southeast and has been faulted along its axis.

Lithologically, the Vaqueros is here a grayish, massive, nonnodular sandstone in which alternating hard and softer beds have influenced the character of the outcrops and given a somewhat castellated appearance to the steeper slopes. The hills in sec. 17, T. 27 S., R. 18 W., are typical of this topography.

Near the southeastern extremity of the Packwood ranch area the following fossils have been found:

Phacoides acutilineatus Conrad.
Pecten andersoni Arnold.
Leda sp.
Tivela ? sp.

Other areas.—A narrow strip of slightly pebbly, grayish glauconitic sandstone underlies the shales of the Santa Margarita(?) and rests upon the Cretaceous sandstones in secs. 3, 10, 11, and 14 of T. 27 S., R. 18 E. No fossils have been found here, but tentatively this "reef bed" is considered of Vaqueros age, as are the sandstones noted near Shale Point. The latter beds dip about 70° NE. and have apparently been faulted into their present position. They contain the following forms:

Pecten andersoni Arnold.
Pecten crassicardo Conrad.
Balanus sp.

DISTRICT BETWEEN BITTERWATER CREEK AND SALT CREEK.

General statement.—South of Bitterwater Creek the areal character of the Vaqueros is quite distinct from that to the north. Instead of broad, much faulted, and crushed zones, the sandstones are exposed in long, well-defined, narrow areas, usually in sharp contrast with the overlying shales of the Monterey and Santa Margarita (?) formations.

In general, the Vaqueros consists of tawny to chocolate brown, rather calcareous sandstones, containing numerous fossils in most places, and at many points consisting of two separate reef beds, the upper separated from the lower by more or less shaly layers. Where sufficiently well defined, this characteristic of the "reef beds" of the Vaqueros has been indicated upon the geologic map accompanying this report.

McDonald's ranch area.—The same anticlinal uplift upon the axis of which is exposed the area of sandstones of the Tejon, described on page 39, has also exposed the Vaqueros. The sandstone "reef," which is the most marked bed of the McDonald's ranch area, completely incloses the Tejon as an elongated loop nearly 4 miles long. At its southeastern extremity the dark, craggy reef contrasts strongly with the less conspicuous Eocene sandstones beneath and the smooth rounded topography of the later shales. The tunnel and well dug at McDonald's ranch show that the Vaqueros on a fresh surface is quite light in color, of a mealy grain, and rather pebbly. Characteristic Vaqueros fossils were found in this area 1 mile northwest of McDonald's place.

Cedar Canyon–Carneros Spring–Temblor ranch area.—The northwestern end of this important area of Vaqueros is masked somewhat by the overlying gravels of the McKittrick formation, which lies unconformably upon all the preceding beds in this part of the Temblor Range. From the prominent sandstone bluffs at the mouth of Cedar Canyon the Vaqueros is traceable continuously along the northeast slope of the canyon to a point north of Walnut Spring, thence southeast past Santos ranch and Carneros Spring to the middle of sec. 14, T. 29 S., R. 20 E., a total distance of about 17 miles. Complex east and west folding just south of this last point has disturbed the regularity of outcrops of the Vaqueros. The Vaqueros is particularly well exposed near the mouth of Cedar Cányon, forms a well-marked high bluff of yellow, cavernous, and (toward the base) somewhat nodular sandstone, which extends about parallel with the ridge 3 miles up Cedar Canyon. The beds here dip northeast at angles varying from 30° to 65° and are in strong contrast with the underlying dark-green shales and sandstones of the Knoxville, against which they rest unconformably. This condition is in places accented by the presence of a scattering conglomerate of dark-colored, cherty, and somewhat lighter quartz pebbles.

In the vicinity of Devilwater Creek the reef bed is underlain by sandy shales with some conglomerate, which, while not distinctly resembling the Vaqueros, are probably a part of it, though in some respects the beds resemble the Oligocene (?) of the Wagonwheel Mountain area. A section of these beds measured here is as follows:

Section of the Vaqueros formation and underlying beds at head of Devilwater Creek.

	Feet.
Brown conglomerate	100
Bluish-gray to green shale, hard brown layers, dark-brown fossil reef	50
Blue-gray sandy shale with hard yellow sandstone	
Hard brown layer beneath which is thin-bedded, light-yellow to gray sandstone with hard brown streaks	

In this section, the last two members are doubtfully, while the upper two are certainly, Vaqueros. The lower beds have been represented upon the map by the tint symbol used for "Undifferentiated Miocene."

West of the 2,923-foot point in sec. 7, T. 28, R. 19, a portion of the shales lying above the "reef bed" becomes sandy, extends toward the southeast in a thickening bed (which reaches its best development in the vicinity of Santos ranch), and pinches out in sec. 7, T. 29 S., R. 20 E. This sandstone is called the "upper reef bed" or the "button bed" because of the presence in it of the little button-like echinoderm *Scutella merriami* Anderson. It is separated from the lower bed by sandy shales, which represent a local modification of the usual Monterey shale. In the transition zone between the Vaqueros and Monterey the more sandy facies are mapped as Vaqueros, the predominatingly shale facies as Monterey. In the center of sec. 22, T. 28 S., R. 19 E., an isolated remnant of probable Vaqueros sandstone forms a syncline upon the Eocene sandstones. The Vaqueros also forms a syncline just north of the second ridge north of Carneros Spring.

From Carneros Spring to the southern part of sec. 15, T. 29 S., R. 20 E., the Vaqueros is typical in color and general appearance, and dips monoclinally northeastward beneath the siliceous light-colored shales of the Monterey; but just at the southern extremity the beds begin to show the influence of the cross folding which has produced the remarkably complex conditions just north of Temblor ranch.

The Vaqueros in the SW. ¼ sec. 14, T. 29 S., R. 20 E., consists of 200 feet or more of hard, dark-brown sandstone and conglomerate. This sandstone contains superficially cracked dark-brown sandstone concretions almost exactly similar to those found in the Eocene or Cretaceous beds. Some of these concretions have been elongated into lenses 10 to 12 feet long and 3 to 4 feet through. At the base of these sandstones is a hard layer 6 to 10 feet thick of coarse fossiliferous conglomerate, which is pitted and very resistant to weathering, and is exposed in vertical walls about 20 feet high. Another coarse layer of sand and conglomerate occurs about 60 feet above that just described.

In this preliminary statement it is unnecessary to enter into a full explanation of the peculiar structural conditions north of the Temblor ranch. Two synclines and a faulted anticline developing toward the northeast from a common point in the northwest corner of sec. 26 have produced peculiar fanlike exposures of the Vaqueros sandstone and of the accompanying soft beds which underlie it at intervals and which have been mentioned as possibly of Oligocene age. The Vaqueros here is conspicuous in its croppings, though not of great thickness, and toward the south end is marked by two parallel "reef beds." A section from the spring in the W. ½ sec. 25, T. 29 S., R. 20 E., across the strike of the Vaqueros beds, is as follows:

Section of Vaqueros sandstone in W. ½ sec. 25, T. 29 S., R. 20 E.

	Feet.
Reef bed of hard calcareous, fossiliferous, coarse sandstone layers	80
Coarse, medium-bedded, slightly concretionary sandstone	200
Bluish to brownish shale, crumbly and not well laminated	20
Fine, thinly laminated sandstone, approaching shale in texture	80
Bluish shale, same as above	15
Thin bed of coarse sandstone	5
Bluish to brownish shale, as above	20
Bed carrying *Ostrea* and many other poorly preserved and unrecognizable fossils	25
	445

The Vaqueros is well exposed on the northeast flank of the Temblor anticline on Temblor Creek northeast of the Temblor ranch house, where the following section is exposed.

Section of the Vaqueros near Temblor ranch.

	Feet.
Hard, dark-brown "button bed"	25
Soft sandy beds	175
Reef bed of very hard resistant material	100–200
Soft, medium-bedded, semiconcretionary sandstone	200
Bluish shale and thinly laminated sandy beds, alternating	250
	650

The most southerly exposures of this area lie in sec. 25, just north of the Section Six Oil Company wells. Here they appear as two low, inconspicuous, gray sandstone reefs considerably faulted and not particularly fossiliferous. Their position marks the southeastern nose of a plunging anticline, the faulted axis of which has been assumed as marking the southern limit of this present group of Vaqueros areas. In this region the Vaqueros yields oil of economic value, and in that connection is described later (p. 200).

Area on summit of Temblor Range.—No fossils whatever have been found in the sandstone believed to be Vaqueros on the summit of the Temblor Range, and its age is therefore indeterminate, but from its position beneath certain siliceous and calcareous shales, which are identical in appearance with the Monterey, and because of its lithological resemblance to sandstones of known Vaqueros age, it has been included with this formation. The area is considerably less regular in thickness and distribution than the beds described on the last few pages, but extends more or less continuously from a point about 1½ miles southeast of Sumner's ranch southeastward along the summit of the Temblor Range to a point about one-half mile north of the head of Salt Creek. A discussion of the structural agencies through the action of which this sandstone is exposed will be reserved for a later chapter. Where the Vaqueros first appears upon the ridge between Sumner's and Walnut Spring, the beds of crushed, light-colored sandstones dip 60° NE. toward Cretaceous sandstone and shale which have been faulted up against them upon the northeast. At first glance one would suppose that the siliceous and yellow-banded shales southeast of this sandstone lie beneath it, but a further study of the relations here and to the southeast indicates that the sandstone has been completely overturned and that its position with regard to the shale is not normal. The fault along the northeast border of this sandstone series is traceable almost to the center of sec. 25, T. 28 S., R. 18 E., where it appears to be replaced by an overturned anticline.

In the gulch in the northwest corner of this section the following sequence, showing a gradation between the sandstone and the overturned shale stratigraphically above it, is as follows:

Transitional Vaqueros-Monterey beds in sec. 25, T. 28 S., R. 18 E.

	Ft.	in.
Yellowish, rather firm sandstone		
White sandstone	10	
Yellow calcareous layer, about		8
White sandstone	5	
Thin yellowish calcareous layer		
Whitish sandstone	15	
Pebbly grit	4	
Fine white shale with a thick yellowish calcareous layer		
	34	8

In this vicinity the usual unconformable relation between the sandstone and the Cretaceous shales beneath is evident. From this unconformable exposure southeastward the sandstone, while well exposed, is less continuous and is at some places greatly flexed, while at others, notably in sec. 4, T. 29 S., R. 19 E., it appears to be a simple monocline dipping about 15° NE. and bounded upon its southwestern side by a well-defined, though probably minor, fault.

Topographically this upland country is smooth and rolling, and at best the Vaqueros exposures are not prominent, but toward the southeast, where Santos Creek and other streams drain into the San Joaquin Valley, they encroach upon the Vaqueros, which becomes a more prominent topographic feature. Thus in the syncline crossing the head of Carneros Canyon the sandstones are exposed in buttress-like tawny croppings similar to those near Santos lower ranch.

There is little or no doubt that the sandstone from the San Luis Obispo County line southeastward to Salt Creek is of Vaqueros age, for near the north line of sec. 19, T. 29 S., R. 20 E., several bivalves suggesting the lower Miocene were found upon the northeast flank of the syncline.

VAQUEROS SOUTH OF SALT CREEK.

General statement.—Within the region south of Salt Creek, which is the most important economically of the whole area studied, the largest single mass of the Vaqueros extends along the summit of the range in an elongated, rather indefinite area extending southeastward from the much-faulted region north of White's camp to sec. 15, T. 32 S., R. 22 E., where it is faulted out of sight beneath the overlying shales.

Other areas in this region lie upon the southwest flank of the Temblor Range and in the hills drained by the several branches which unite to form Bitter Creek. Because of the intense faulting upon the Carrizo Plain slope of the Temblor Range it has been difficult to properly differentiate the sedimentaries there, and all statements concerning not only the structure but the age of the sandstones described as Vaqueros must be considered as merely tentative. Until extended detailed work can be done in this region definite statements are to be avoided. Except for the narrow well-defined bed of Vaqueros making up the base of the Miocene of the south arm of the Temblor anticline and for the Bitter Creek area, no Vaqueros has been found upon the northeastern flank of the Temblor Range south of Salt Creek.

Area on summit south of Salt Creek.—The northern end of this area is much shattered by blocks of old granitics and schists which have been faulted up, apparently from a very great depth. Especially upon the southwest side of the range the Vaqueros sandstone is sheared. Further, the relations of the Vaqueros to the rocks immediately adjacent are masked by gravels of the McKittrick formation, which here lies unconformably upon all older rocks. Upon the northeastern slope of the mountains the sandstone extends northwest and southeast as a narrow zone steeply tilted to the northeast and is overlain by calcareous and arenaceous shales, apparently of Monterey age.

The base of the sandstone here has been faulted down against a schist block, so that the determination of the original thickness of the sandstone is not possible. The Vaqueros in this vicinity is a light-brown, much-softened sandstone, containing narrow bands of dark-brown to blackish shale which seem to be more prominently developed upon the southwest side of the summit than upon the slope toward Crocker Canyon. The heavily bedded sandstone in the axis of the anticline, about 3 miles north of White's camp, has a concretionary tendency, the concretions being irregular and from 10 to 12 feet in diameter. The material is a fairly coarse granitic sand with a few black grains scattered through it. In the vicinity of Smith's wells the dark shales associated with the Vaqueros carry considerable sulphur. Characteristic exposures of the Vaqueros in this area are obtained along the new graded road between Crocker Spring and White's camp, where the buff to brownish, rather coarse sandstones, with intercalated shales, are shown upon the cuts of the road.

From the Crocker Spring and White's camp road southeast along the slope of the range, the sandstones are bounded upon both the northeast and southwest sides by faults. They have been complexly folded and are so crushed and softened that the usual rather bold exposures characteristic of Vaqueros are not to be found there. In sec. 5, T. 32 S., R. 22 E., the normal relations of the Vaqueros to the overlying shales can be noted upon the southwest slope of the 3,550-foot point. This slope is steep from the summit downward for about 1,500 feet, where the underlying sandstones occupy the east arm of a local anticline and pass beneath the shales which here make up the summit of the range. Unless this condition is due to an overturn of the sandstones a normal relation to the shales is definitely established. This condition continues only about a mile to the southeast, where the shales are again faulted against the sandstone.

At its southern end, the sandstones of this area appear to be monoclinal, with dips of 30° to 70° SE. Through the coalescence of the two faults bounding the Vaqueros, the broad area of sandstone narrows to a wedge, which ends just at the north line of sec. 15.

Areas on southwest flank of Temblor Range.—A number of disconnected areas of sandstone, which are presumably of Vaqueros age, have been noted upon the southwest flank of the Temblor Range. Their structure is usually obscure and they have been mapped with an attempt only at approximate accuracy. They may be described as generally coarse to medium grayish and brownish yellow sandstones, which nearly always have been greatly softened and sheared by the faulting to which they have been subjected. The three areas east of Wolfort's ranch occupy the axis of an anticline which has been faulted upon its southwest arm so that the sandstones now occupy a normal position with reference to the overlying shales only upon their northeast side. About 1½ miles southeast of Sandiego Joe's, a small area of sandstone, presumably of Vaqueros age, is exposed upon the axis of an anticline. Similar exposures occur to the southeast along this same axis and an elongated area of Vaqueros is faulted up against the McKittrick in the southeast part of T. 30 S., R. 20 E. There the beds of this area are apparently overturned, but toward the southeast in sec. 6, T. 31 S., R. 21 E., they form a normal anticline and plunge southeast, passing beneath the Monterey shale.

Crocker Spring area.—One-half mile due west of Crocker Spring there is a zone of supposed Vaqueros sandstone extending northwest and southeast, along the southwest side of which there is a fault. The sandstone in this zone is hard, gray, and moderately coarse-grained, and is immediately overlain by a dark-brown shale with one or two interbedded sandstone layers, each probably a couple of feet in thickness. Above these sandstone layers are regular dark yellowish-brown calcareous layers and concretions. From here upward in the series the material is transitional into hard porcelain shales with occasional yellowish layers.

Vishnu area.—In sec. 23, T. 32 S., R. 22 E., about 1 mile east of the Vishnu well, and extending southeast along the flank of the Temblor Range to sec. 4, T. 11 N., R. 25 W., there is a narrow area of the Vaqueros formation. This area consists of brown shale and a coarse sandstone which has been stained somewhat pink in places by oil. It may be considered within the transitional zone of shale and sandstone between the lowest Monterey and the highest Vaqueros. This sandstone has certainly been faulted along its southwest margin, but may be in normal contact with the shales toward the northeast.

Bitter Creek area.—In the southern half of T. 11 N., R. 24 W., is a roughly elliptical area of Vaqueros which extends from Cienega

Creek on the southeast to the head of Elkhorn Plain on the northwest. These sandstones are overlain upon the northeast by the Monterey shale and are bordered on the southwest by the shales of the Santa Margarita (?) formation, which, except at the head of the gulch in the southwest corner of sec. 28, has completely obscured the Monterey shale. Two major structural lines cross this area from northwest to southeast and have been instrumental in exposing the sandstone at the surface. This sandstone is in general evenly bedded, usually coarse and granitic. In some places, notably in the canyon back of Sunset, it is concretionary and is often well impregnated with oil. It is undoubtedly a part of the same series that is so well exposed upon the southwest flank of the Temblor Range near the Smith and White camps. This area is the most southerly of the supposed Vaqueros that has so far been examined in the Temblor Range.

AREAS ALONG THE SOUTHWEST MARGIN OF CARRIZO PLAIN.

A rapid reconnaissance along the foothills of the southwest side of Carrizo Plain from García's ranch to Painted Rock ranch showed the existence of a series of faulted and folded sandstones and interbedded shales which are, in part at least, of Vaqueros age.

One of the best sections of the Miocene in the whole McKittrick-Sunset region is that exposed on the southwest flank of the syncline in the southeast quarter of T. 29 S., R. 17 E., and in this the Vaqueros is a series of rather soft, tawny and gray, medium to coarse sandstones, which has here a total estimated thickness of 1,000 feet. The transitional character of the uppermost sandstone of the Vaqueros into the Monterey shale overlying it is clearly shown in this section.

The Vaqueros in this vicinity is associated with dikes of diabase, which were intruded into the soft greenish-brown shales below the reef beds before the deposition of the sandstone, since rounded basal pebbles of diabase are found in the Vaqueros. Other dikes and sills of similar rocks, on the other hand, are definitely intrusive in the Vaqueros, and even, as in sec. 5, T. 30 S., R. 18 E., penetrate the Monterey shale. Except within this limited area and at a single point about 8 miles southeast, there are no exposed Miocene intrusives in the McKittrick-Sunset region.

A typical Vaqueros fauna has been collected from the beds about 1½ miles due west of Painted Rock ranch, where light-colored, well-bedded sandstones dip northeast against a faulted block of brownish-yellow hard shales of doubtful age.

Northwest of the Painted Rock ranch similar yellow shales are interbedded with sandstones which may be of late Miocene age. The relations are most clearly evident in the broad anticline occupying the hills about a mile west of bench mark 1930, in secs. 4, 5, 8, and 9 of

T. 31 S., R. 19 E. Here the white medium-bedded nonnodular sandstone at the axis of the fold is overlain by sharply contrasting beds of hard yellow and buff shales, beautifully exposed in the ridge upon the northeast arm of the anticline. The shales are overlain by grayish, medium-grained, well-bedded, northward-dipping sandstones, which outcrop prominently in the spurs and knobs in secs. 30, 31, 32, and 33 of T. 30 S., R. 19 E. The upturned beds are offset and sheared by vertical north and south faults, which traverse the strike of the series at right angles.

An interesting sand-filled and cemented fracture, which belongs to the same system as the faults, extends northward across sec. 4, T. 31 S., R. 19 E., from its southwest corner, and resembles a low, partly demolished wall, especially from the south. Upon the summit of the ridge in the SW. ¼ sec. 32, T. 30 S., R. 19 E., parallel to and just east of the fault which brings sandstone against shale, a basic dike 3 or 4 inches wide penetrates the shale. Although of finer grain, the rock resembles that several miles northwest.

The age of this series of shales and sandstone is not at present known; hence upon the geologic map only the lithologic differences and structural conditions are indicated.

THICKNESS OF THE VAQUEROS SANDSTONE.

The following figures are based upon paced meanders or estimates made in the field and represent either minimum-maximum measurements or averages for a given locality:

Thickness of Vaqueros sandstone in McKittrick-Sunset region.

	Feet.
Devils Den region	25–150
Near McGovern ranch	2,300
Near McDonald ranch	300–450
At Napoleon Spring	530
Media Aqua Creek (including 2 "reef beds" and included shales)	800
Three-fourths mile south of McAllister's ranch on road	300
Near spring in sec. 25, T. 29 S., R. 20 E	450
Hills 7 miles west of Simmler	1,000

MONTEREY SHALE (LOWER MIDDLE MIOCENE).

INTRODUCTORY STATEMENT.

The term "Monterey" has been applied by previous writers to the whole of the prominent series of white shale extending uninterruptedly from just east of Polonio Pass southeastward along the flank of the Temblor Range nearly to Temblor ranch, and to the great area of shale embracing practically all of the range from the head of Salt Creek southeast to the limits of the region studied. The examination carried on during the past season has shown that this shale is separable into two formations, one of which is thought to be the equivalent of the

Santa Margarita(?) formation (upper middle Miocene) in the Coalinga region, while the earlier more closely resembles the Monterey (lower middle Miocene), as it has been described in other parts of the State. Definite paleontologic evidence for the separation in the McKittrick-Sunset region has been scant, but beyond the limits of the mapped area, west of Polonio Pass and upon the southwest side of Cholame Valley, white shaly beds that are believed to be equivalent to the diatomaceous beds of the Antelope Valley locality are known to overlie beds of Santa Margarita age. The main consideration involved in the present separation of the rocks, however, is one of convenience to the prospector. Since there is a marked difference in the physical appearance of the rocks, it simplifies an understanding of geologic and structural conditions, both important in governing the distribution of petroleum, if the separation into Monterey shale and Santa Margarita(?) formation be made. The rocks included within the Monterey are considered to be the source of much of the petroleum in California, and so have been studied in considerable detail.

GENERAL DESCRIPTION.

The general characteristics and origin of the Monterey formation have been fully described in Bulletin 322 of the United States Geological Survey, and this description will apply with slight modification to the rocks of the McKittrick-Sunset region.

Broadly speaking, there are but two great Monterey provinces in the McKittrick-Sunset region. One begins just south of Polonio Pass and extends southeast along the northeast face of the Temblor Range nearly to Temblor ranch, where it terminates abruptly in the belt of cross folding affecting the Vaqueros and older rocks. The other and larger area of Monterey begins in the San Andreas fault zone immediately east of Sumner's ranch in sec. 31, T. 27 S., R. 18 E., extends southeast along the southwest side of the Temblor Range to the vicinity of Wolfort's ranch, where it rapidly broadens to include practically the whole mass of the range, and so persists southeastward to the limits of the region studied.

The Monterey of the McKittrick-Sunset region consists of a series of brownish to light-yellow shales, usually well bedded and resistant to weathering, which are largely of organic origin. The lowest portion of the series is usually made up of calcareous and arenaceous shales which represent a transition into the sandstones and fossiliferous beds of the Vaqueros. These grade upward into typical siliceous and argillaceous shales that contain evidence of organic origin. Prominent zones of nodular calcareous shales are characteristic of this middle portion of the series. The upper third of the formation includes an indefinite zone of sandstone beds that are irregularly intercalated in limy-siliceous shales. The succession and character of these sediments coincides very closely with those of the lower division of the Monterey in the Santa Maria district. The upper division, so prominently developed near Lompoc, in the Santa Maria district, is absent from the McKittrick-Sunset region, unless the basal organic shales of the formation here described as Santa Margarita (?) formation are the same as those described as upper Monterey in the Santa Maria report.

The conditions under which deposition of the Monterey shale of California took place were unique and are not yet entirely understood. Most of the Cretaceous and practically all of the Tertiary deposits up to those of middle Miocene time, with the exception of certain Eocene or possibly Oligocene shales in the Coalinga region, are of mechanical origin. But with the sharp change in conditions at the close of the Vaqueros epoch, a new type of sedimentation began. With a few alternating returns to shallow-water conditions, indicated by the transitional sandstone beds at the base of the series, the ocean floor was evidently greatly depressed, and the area of land surface correspondingly restricted.

The waters of this ocean were scantily supplied with molluscan life, but must have teemed with the minute foraminifera and diatoms, the skeletons of which, falling to the ocean bottom, have formed such a great bulk of the Monterey shale. After the major portion of the lower division of the Monterey had been deposited, there must have been a partial return to the shallow-water conditions which resulted in the production of local areas of sandstone, some of them fossiliferous. That portion of middle Miocene time which succeeded the period of sandstone deposition was peculiarly adapted to the growth of diatoms, the remains of which make up a high percentage of the shales above the upper sandstone horizon.

The Monterey shale has been subjected to a varying degree of alteration, none of it pronounced enough, except in certain restricted localities, to greatly change the appearance of the formation. Silicification has taken place, however, especially in the lower and middle portion, but the process by which the silica was so intimately introduced into the shales is not fully understood. A suggestion is at hand in secs. 13 and 14, T. 30 S., R. 21 E., where an intense local silicification has taken place along fractures in a much folded and possibly faulted zone of the Monterey. The rock has been so altered as to closely resemble both in hardness and color the grayish-green phases of jasper and chert seen in the pre-Cretaceous Franciscan formation. It is conceivable that solutions percolating along similar, though perhaps smaller, fractures resulting from the folding and faulting to which the Monterey shale has been subjected have produced a less intense but none the less definite silicification in other parts of the series.

ANTELOPE VALLEY—TEMBLOR AREA.

The northwestern extremity of the Antelope Valley–Temblor area is a narrow zone of arenaceous shales with some thin beds of sandstones, which occupies the axis of a broad syncline in the NW. ¼ T. 26 S., R. 17 E. The transitional character of these beds into the underlying Vaqueros is clear there. This particular portion of the area is truncated by a fault at its southern extremity and so is separated from the rest of the series extending along the southwest side of the valley and thence southeastward. The shales here are strongly deformed and faulted. The original soft, somewhat sandy character, due to their transitional position with reference to the Vaqueros, has aided in obscuring the structure. On the west side of the south end of Barril Valley a prominent point is occupied by a thick fossiliferous sandstone bed intercalated in the shales. It is a light-gray rock which contains calcite in veins and small masses and varies from fine to coarse in texture. This arenaceous phase of the Monterey, with occasional lenticular sandstone beds, extends through the hills in front of Packwood's ranch and becomes more calcareous toward the southeast. The following section across the northeast area of the faulted anticline south of Packwood's shows the general character of this part of the formation. The section is based on a paced meander from southwest to northeast along the ridge extending diagonally across sec. 16, T. 27 S., R. 18 E., and certainly includes in its upper portion diatomaceous beds classed upon the map as Santa Margarita(?) formation.

Section of middle Miocene in sec. 16, T. 27 S., R. 18 E.

		Feet.
	Grayish white shales to synclinal axis	650
	Pearl-gray shales	220
	Grayish to white shales with quartzitic sandstone dikes across bedding, also large cream-colored nodules	1,330
Santa Margarita(?) (3,500 ± feet).	Soft shale and plentiful yellow layers; upper portion contains some hard white shales	360
	Punky gray shales with several yellow calcareous layers	900
	Soft gray shale with calcareous, and near top gypsiferous layers	295
	Rather punky gray shales with layers of yellow calcareous beds	650
	Gray sandstone with fossil pectens	150
Monterey (3,500± feet).	Poorly exposed white shales, probably vertical	860
	Light-gray thin-bedded shales with thick yellow layers	180
	Gray shales with thin yellow layers	290
	Soft yellow and gray shale	280
	Thin-bedded and shaly sandstone	450
	Gray sandstone	130
	Fault zone, crushed shale and sandstone, structureless in beds, transitional to Vaqueros	255
		7,000

The succession and character of the beds exposed in this section are typical of the Monterey from Bitterwater Creek southeastward for a number of miles—briefly, a series of calcareous and clayey shales, arenaceous toward the base and organic in the upper portion.

The smooth, rounded, and tentlike topography which distinguishes both the Monterey and the Santa Margarita (?) is particularly evident in the hills along the northeast side of Cedar Canyon, as seen from above Packwood's. There is a strong contrast between these bright smooth slopes and the somewhat rugged bluffs of the Vaqueros or the somber Cretaceous mass upon the south side of the canyon.

From Santos ranch southeastward the character of the shale changes somewhat. The whole series becomes less clayey and more diatomaceous, especially in the foothill region due east of Carneros Spring. The following succession of beds has been noted in the canyon about 3½ miles east of the spring, beginning with the uppermost Monterey:

	Feet.
Soft white to lavender organic shales	2,800
White well-bedded shales with limy layers	3,000

Most of this section is exposed in steep northeastward dipping beds of shale along the south side of the canyon. In secs. 2, 11, and 12 the shales are well impregnated with petroleum, which has been prospected in times past at a series of pits dug along the most productive portions of the shale. On the steep bluff in the NE. ¼ sec. 11 the succession in these beds is as follows:

Section of middle Miocene in sec. 11, T. 29 S., R. 20 E.

Hard grayish white shale with yellow layers considerably impregnated with petroleum.
Fine hackly shales considerably impregnated along bedding planes.
Massive arenaceous shales with yellowish limy layers.

A total thickness of about 500 feet is included in these beds.

SANDSTONE DIKES IN MONTEREY SHALE.

Upon a hill in the southwest quarter of sec. 3, T. 29 S., R. 20 E., yellow Monterey shale is traversed by three sandstone dikes which strike slightly east of north and dip about 60° W. The lower is about 8 feet thick and the middle and upper about 18 and 8 feet, respectively. They consist of rather uniform, fine to medium grained granitic sand, and are longitudinally seamed with irregular calcite veins varying from a mere thread to an inch in thickness. Although the structure is not discernible in these dikes, they weather to a rough and pitted surface on which the calcite veins stand out and give a false appearance of bedding. Several shale inclusions were noted in the sandstone of the dike.

DISAPPEARANCE OF MONTEREY SOUTH OF GOULD HILLS.

A broad overlap of the gravels and shales of the McKittrick, in conjunction with cross folding, has buried the Monterey south of Gould Hills, except where two V-shaped remnants are left in the axes of two closely-folded synclines north of Temblor ranch. These small areas indicate a former connection between the area just described and that to follow. In fact, it is most likely that the broad Cretaceous and Eocene core of that part of the range which extends from Cedar Canyon to Temblor ranch was once completely covered by Monterey shale.

SUMNER'S RANCH—SUNSET AREA.

The Sumner's ranch–Sunset area of Monterey is the most important in the region under discussion, although at its northwest end it is a mere strip of calcareous yellow shale which is undoubtedly truncated at a very low angle by the fault along its southwestern margin. The exposures in the creek bed just east of Sumner's house are a much folded and silicified calcareous shale in which springs rise and flow into Bitterwater Creek. The exposures of Monterey thence southeast are not of the best, owing to severe crushing, yet it is evident from the abundance of calcareous nodules that the horizon is near the base of the series, a position which is definitely established a short distance farther southeast by its relations to the overturned Vaqueros along the summit of the range.

From near Wolfort's, the area broadens and swings across the Temblor Range so as to include a much greater bulk of the mountains. A large part of the eastern half of this wider portion is a single great synclinal structure which begins in a series of faults north of Wolfort's and extends southeastward along the range for about 18 miles. Santa Maria Valley and the high flats southwest of Temblor ranch are the topographic expression of this structure. At its northwestern end the shales are interbedded with quartzitic gray sandstones well shown along the road between McKittrick and Simmler just east of the summit. These sandstones are believed to be a portion of the zone of lenticular sandstones noted elsewhere in the area, particularly in the vicinity of Crocker Spring and along the eastern slope of the range southwest of Midway and Spellacy Hill.

Although the series maintains its calcareous character, there appears to be an increase in the degree of silicification from Sandiego Joe's southeastward. This is shown by such bands as the continuous zone of almost cherty shale extending from just southwest of the 4,110-foot point in sec. 10, T. 30 S., R. 20 E., along the summit of the range to Crocker Spring. A similar siliceous stratum, in which the shale is of a porcelaneous type, lies near the top of the Monterey. It appears to be a silicified diatomaceous shale.

The steep southwest wall of Salt Creek canyon exposes a fine section of the Monterey, which is there a southwest dipping monocline of platy, limy, siliceous yellow shale, containing hard yellow, limy concretions which are seamed with numerous small calcite veins. After long exposure to the weather, the less resistant portion of the concretions is dissolved away and the harder veinlets left in bas-relief. This sort of weathering is typical throughout the whole series, wherever there is differential hardness in the calcareous portions of the shales. Of such character are the shales a couple of miles west, and as far south, of Frazer Spring.

This phase of the shale occurs also at the south end of Santa Maria Valley in the broad flat-topped ridge lying mostly within sec. 6, T. 31 S., R. 22 E.

The topography of the uppermost beds of the Monterey southwest of Midway contrast rather sharply with the lower smooth slopes of the softer shales of the Santa Margarita(?) formation. The former is clayey and carries more numerous and more thinly bedded brownish-yellow calcareous concretions than exist higher in the series. The steeply northeastward dipping shales at Crocker Spring are probably in this upper zone of the Monterey.

In all the folded upland region along the summit of the Temblor Range there is little lithologic variation in the Monterey shale except that due to folding or faulting. The intergradationary character of the Monterey and Santa Margarita(?) and their close resemblance is, nevertheless, very evident along this zone; beds of coarse granitic cobbles, such as characterize the typical Santa Margarita, are found well down in the transitional beds, and even at one place in a canyon near the center of sec. 11, T. 32 S., R. 22 E., are intercalated with shales of a distinctly Monterey character.

Immediately west of Maricopa, near the brea deposits, beds of coarse granitic sandstone from 1 to 2 feet in thickness are interbedded with platy diatomaceous and gypsiferous shales. These contain fragments of shale and of the yellow limestone concretions which are common in the calcareous shales. Although some of this sandstone may be in the form of dikes, the fact that it parallels the bedding, together with its occurrence as lenses elsewhere in the field, leads to the conclusion that it exists as true beds. The change from sandstone to shale is very sharp. A saline spring, the waters of which carry blebs of oil, rises in the shales here and has been instrumental in producing the bed of brea near by.

In the SW. ¼ sec. 21, about 3 miles southwest of Maricopa, yellowish-brown shales and thin-bedded granitic sandstone and sandy clays are interbedded and form the transitional beds at the base of the Monterey.

The most southerly portion of the Monterey area within the region studied lies south of the Pioneer group of oil wells, and a paced section running from sec. 24 southwest into the NW. ¼ sec. 25, T. 11 N., R. 24 W., gives the following measurements:

Section of Monterey shale south of Pioneer oil wells.

	Feet.
Hard siliceous shales with yellow layers	1,700
Fine white and yellow shales	700
Calcareous and arenaceous shale with calcareous nodular layers	500
	2,900

The fairly constant character of the Monterey shale throughout the whole McKittrick-Sunset region is evident in a comparison between this section and those made in other parts of the area.

A tongue of brownish to gray and sulphur yellow diatomaceous shale of Monterey age is exposed just at the edge of the map in sec. 32 of T. 11 N., R. 24 W. It is overlain directly by the Santa Margarita(?) formation, which here consists largely of shale fragments. The poverty of the Monterey in paleontologic remains is here, as elsewhere in the State, very striking. With the exception of a few *Pecten peckhami* Gabb, *Macoma, Arca,* a single specimen of *Dentalium,* some bits of fish scales and bones, and ostracod impressions, the shales have yielded nothing which would assist in determining the age of the series. The establishment of this point has, therefore, been based upon its general lithology and position with relation to formations of known age.

IMPORTANCE WITH RELATION TO PETROLEUM.

The organic matter in the Monterey shale is believed to be the source of at least a part of the oil in the McKittrick-Sunset region; its presence or that of the Santa Margarita(?) is therefore believed to be necessary for the accumulation of petroleum in this territory. Most of the hydrocarbon content has migrated to other formations, and entered the Vaqueros below or the McKittrick above, so that as a reservoir the Monterey is not important. An exception to this statement might be made in case of the interbedded sands near its base or in the transition zone between it and the Vaqueros. The Monterey is important, however, as the cap which overlies the oil in the Vaqueros, and through which one must drill to reach it. For this reason a study of the thickness of the Monterey and of the structural lines which affect it are important in determining where the probabilities are greatest for securing commercial quantities of oil.

SANTA MARGARITA(?) FORMATION (UPPER MIDDLE MIOCENE).

GENERAL STATEMENT.

The reasons which have led to the correlation of the diatomaceous upper portion of the shale series in the McKittrick-Sunset region with the Santa Margarita formation have been given in the discussion of the Monterey shale. (See pp. 55-56.)

The Santa Margarita in portions of the Coast Ranges is separated from the Monterey by a great unconformity, as at points along the west side of the Salinas Valley. Elsewhere an apparent conformity between the two formations is the rule. Although conformity prevails over the greater portion of the region under discussion, both of these conditions are found here.

For convenience of discussion the region has been divided into areas, each of which is described below.

AREA IN DEVILS DEN DISTRICT.

A roughly triangular area of Santa Margarita(?) occupies the hills extending south from Dagany Gap to Emigrant Hill and west almost to Devils Den. It consists of a series of calcareous and diatomaceous shales, very regularly bedded, which lie in direct contact with the Vaqueros. The complete absence of the Monterey here indicates that the conditions attendant upon the deposition of the Santa Margarita(?) were similar to those in the Coalinga region.[a]

The area is, in fact, the southeast termination of the anticline of Pyramid Hills and the great syncline of McLure Valley, although the simplicity of both structures is here disturbed by the development of many minor folds.

The following section of the full thickness of the formation is based upon a paced meander from the reef bed in the NW. ¼ sec. 11, T. 25 S., R. 18 E., northeastward along the gulch heading near the reef, to the region of the Kettleman Plains in sec. 2.

Section of the Santa Margarita (?) formation in secs. 2 and 11, T. 25 S., R. 18 E.

	Feet.
Argillaceous and diatomaceous dove-colored shales showing near top some evidence of impregnation	1,200
Thin-bedded whitish to yellow shales with russet-colored layers at base	600
Reef bed of fossiliferous sandstone about 75 feet thick (Vaquerous).	
	1,800

This succession and thickness of shales is maintained throughout the area. The topography of the shales is characteristic. The terms "Tent Hills" and "Pyramid Hills," applied to occurrences of the Santa Margarita(?) farther north, fitly describe the appearance of the groups and rows of white or yellowish steep-sided though smooth hills in this vicinity.

[a] Bull. U. S. Geol. Survey No. 398, pp. 88-94, 174-176.

AREAS IN BITTERWATER DISTRICT.

Although, strictly speaking, the larger of the two areas in the Bitterwater district might be broken up into several smaller isolated portions, the structural unity of the whole is unbroken. It begins near Polonio Pass as a faulted block of light-colored diatomaceous shale, with some interbedded sandstones, extends southeastward along both sides of Raven Valley, and finally passes beneath the gravels of the San Joaquin Valley in sec. 28, T. 27 S., R. 19 E. On the northeast side of this pass, in secs. 30 and 32, there are three small isolated areas of light-colored organic shales, which dip against and under beds of Cretaceous age. They are undoubtedly the exposed portions of a wedge of Santa Margarita(?) shale which has been thrust under the older Cretaceous beds to the northeast, during some of the intense deformational action to which the region has been subjected. Except for a small exposure in sec. 33 the series does not appear elsewhere at the surface on the north side of Antelope Valley.

At McGovern Gap, however, the following approximate section has been measured:

Section of Santa Margarita (?) formation at McGovern Gap.

	Feet.
(*a*) White and bluish-gray easily fractured shale	150
(*b*) Fine-grained brownish sandstone with some shales	395
(*c*) Calcareous organic shale, well bedded and light in color. Contains some sandy layers	1,200
(*d*) Sandstone beds with some shale intercalated	300+
	2,045

South of this are nodular typical shale and dark-green sandstone of the Cretaceous which have been faulted up against the Miocene.

A slight lavender tint in the sandstone toward the top of the series is the only indication of petroleum in the vicinity. The conditions of deposition were not particularly stable, since within a mile southeast a geologic section shows that (*a*), the uppermost shale, has thickened to 500 feet while (*b*) is represented by only a few layers of sandstone. Similarly the 1,200 feet of organic shales are reduced in thickness to but 700 feet, while the lowest sandstone bed (*d*) becomes shaly and increases to a thickness of some 400 feet. Such facts indicate local variations in quantity and quality of the material deposited, a characteristic of sedimentation found nearly everywhere in the State, even among the oldest rocks.

The northeast limb of the great Raven Valley anticline is a series of soft drab diatomaceous and somewhat harder calcareous shales with some intercalated harder clay shales of a bluish gray color, which have lent themselves easily to the structure imposed upon them. There have been produced in these shales a series of divergent anticlines and synclines which, though complicated, are traceable across the white barren hills. At Shale Point there is an outcrop of coarse granitic sand containing much gypsum and stained through several tints of lavender to brown. The shales in the vicinity are rather soft, light in color, and contain hard calcareous yellow concretions sparingly. A similar bed of sandstone occurs in the shales about 1 mile south of Alfonso's. At one point this appears to be an interbedded sandstone, but at another it as certainly cuts across the strike of the shales and has probably been pressed into its position as a result of folding. Two miles southeast of Ravens Pass a great mass of dark-brown to pinkish, rather coarse sandstone, striking about S. 40° W., cuts through a prominent hill to and slightly beyond the summit. The sandstone has a jagged contact with the shale and is evidently of the same nature as the dikes already described. Reference to the section northwest of Alfonso's, described in the Monterey discussion (p. 58), will give an idea of the character of the Santa Margarita(?) formation south of Bitterwater Creek, since this portion is an extension of the south arm of the Packwood anticline which swings toward the east near Alfonso's camp.

Another area of Santa Margarita(?) extends along the summit of the range immediately southwest of McDonald's ranch for nearly 3 miles. It has been preserved in the axis of a prominent syncline and represents only the basal portion of the formation. The peculiar yellowish to brown calcareous zone which is characteristic of the formation north of McDonald's is found here also.

AREAS IN TEMBLOR DISTRICT.

For nearly 9 miles southeast of McDonald's ranch, the shales of the Santa Margarita(?) are not certainly present, since the eastward swing of the folds controlling the distribution of the shales undoubtedly places the series considerably east of the lowest foothill exposures, so that they there lie completely buried beneath the superficial deposits of the valley margin. In sec. 29, T. 28 S., R. 20 E., the basal shales of the series emerge from beneath the valley floor as the uppermost beds of a monocline which dips about 50° NE. The soft lavender to white diatomaceous and semiporcelaneous shales are beautifully exposed in the smooth bare hills extending from here parallel with the McKittrick road as far southeast as the canyon along the northwest side of the Gould Hills, where their angular nonconformity with the overlying McKittrick formation is very marked. Strong evidence of petroleum impregnation has been found in both the gravels and sands above the Santa Margarita(?) in this vicinity, and in the Monterey shale below, although the diatomaceous beds themselves are comparatively free from evidence of petroleum content. At the Gould Central wells in the SE. ¼ sec. 7, T. 29 S., R. 21 E., such is not the condition, however. There a small area of soft light diatomaceous shale of supposed uppermost Santa Margarita age is heavily charged with asphalt, while the sands of later age, which completely surround the shales, are likewise well impregnated.

Between Gould Hills and Frazer Spring, the McKittrick gravels, sands, and travertine deposits have so far encroached upon the older formations that the Santa Margarita(?) has been completely buried.

AREAS IN McKITTRICK DISTRICT.

General statement.—While the three areas exposed in the McKittrick oil district will, for convenience, be treated separately, it must be remembered that these are but the exposed portions of an undoubtedly continuous zone of shales which, south of McKittrick, swings southwest toward Crocker Spring and thence, without visible break, along the flank of the range as far as Spellacy Hill. The popular misconception as to the existence of a "break" between McKittrick and Midway appears to have arisen from the present lack of development in the Crocker Spring region, coupled with the peculiar structural conditions. In a later discussion of the structure facts will be stated which indicate the continuity of the Santa Margarita(?) from McKittrick to Midway. (See pp. 69–71.)

McKittrick area.—The largest and commercially most important of these areas appears about three-fourths of a mile west of Frazer Spring as a narrow strip upon the axis of a wavy anticline which plunges toward the northwest. Just southeast of the spring it becomes very wide, extends along the foothills through the developed McKittrick territory, where it is nearly 1½ miles across, and thence passes along the northeast flank of the prominent ridge in secs. 28, 33, and 34, T. 30 S., R. 22 E., as a more and more restricted zone, until almost at the middle of the N. ½ sec. 34 it disappears beneath the later accumulation of sand and gravel of the McKittrick formation. Within or adjacent to this area of the Santa Margarita(?) lie all the producing wells of the McKittrick field. A thorough understanding of the lithology and complex structure of the district is, therefore, essential to any consideration of future economic development.

At the northwest extremity of the area the shales are diatomaceous and include siliceous and thin yellowish layers. A curious feature noted southeast of Frazer Spring is that where these shales have been exposed to weathering agencies, as on open slopes and ridges, they appear considerably harder than in fresh cuts. The brick red to crimson stains in the shales, and at the base of the overlying McKittrick in the bluffs just east of the road near Frazer Spring, are probably due to gypsum and to the oxidation of hydrocarbons that have risen along the fractures of the anticlinal axis in the shales at this point.

The general character of the shales of the Santa Margarita(?) formation at the north end of the McKittrick field is shown in the small canyons in the N. ½ sec. 13, T. 30 S., R. 21 E. Here the shales weather white and yellowish, but show a purplish to chocolate-brown color on the fresh surface, due to the complete impregnation with oil. The shale is mostly diatomaceous, although some layers approach the semiporcelaneous condition. The rocks here are strongly contorted and the structure is by no means clear. Semi-porcelain and soft shales with dark-brown calcareous layers are underlain by thinly banded dark (except on weathered surface) brown diatomaceous shales, somewhat punky, much folded and crushed.

In the more closely folded portions of the area, especially where the shales have been fractured to any degree, there are deposits of brea or even of petroleum about the orifices of live springs, and these indicate conditions favorable to the concentration of the oil content of the rock.

The general physical character of the shales throughout the area does not vary greatly, except that in some places, usually not far below the base of the McKittrick, the shale becomes more or less gypsiferous. It has also been noted that the more punky, less resistant shales occur where structural activities have been pronounced, as along anticlinal axes and in fault zones.

With the exception of a few very thin bands encountered in some of the wells, and a doubtful lens south of the Providence (Dabney) lease, no sandstones have been found intercalated in the Santa Margarita(?) here.

From the northwest corner of sec. 29 southeastward, the extent of the area is controlled by a strong anticline, and along this portion of the structure there is a most instructive display of the conditions governing the accumulation of oil. While the axis of the fold lies wholly within the Santa Margarita(?) it is flanked on both sides by the sands and gravels of the McKittrick formation, which dip away from it at angles varying from 30° to 60°. The shales of the Santa Margarita(?) are of the usual diatomaceous character and exhale a rather pungent petroleum odor from the freshly broken brownish surface. At some points, especially along the contact with the McKittrick on the south side of the anticline, the shales are so pulverent that the foot sinks several inches into the apparently firm surface. This material resembles lycoperdon powder in physical appearance. While this particular phase is extreme, it suggests the general character of the shale along the anticline. In sharp contrast, however, are certain harder yellowish calcareous layers, which weather to a rough surface and break into fragments that often cover the whole slope below such an outcrop.

Less than one-fourth mile due south of the Dabney (now the Providence) headquarters, and just east of the Midway road, is an isolated hill of grayish sandstone which appears to be a closely appressed syncline of McKittrick formation folded into the underlying Santa Margarita (?). Immediately south of this hill and parallel to it is a small lens of fine-grained brownish sandstone about 18 feet thick, which is apparently interbedded in the vertical shale, but shows at one place that it has been either pushed or sifted into fractures which cut across the bedding of the inclosing shale. The lens contains small shale inclusions. It has the peculiar oblique and more or less angular jointing common to sandstone dikes, and shows on the weathered surface a semiconcretionary structure. If this small area is a sand-filled fracture, the source of the material is obscure. The sandstone is well impregnated with oil. One-half mile east of here and north of the axis are similar masses of sandstone, but their relation to the shale is much clearer. At this point the anticline is overturned toward the northeast so that the sandstone, which is roughly parallel to the bedding of the shales, dips very steeply southwest. Its contact with the shales, especially on the south, is very irregular, and indicates that the surface of the shales must have been pitted and honeycombed before the sands accumulated. Irregular masses and lenses of shale within the sand itself are harder to explain, but may be fragments fallen from an overhanging bluff of shale during deposition of the sand upon a weather-beaten and precipitous rocky shore. The presence of an irregular scattering conglomerate of dark porphyry, schist, quartz, and granite pebbles at the base of the sandstone further emphasizes the likelihood of such an origin. Above the sandstones (to the northeast) are conformable beds of rather soft greenish to cream-colored argillaceous shales of McKittrick age, and hence it is practically assured that the sandstones are the basal beds of the post-Santa Margarita (?) formation. They continue to the southeast along the flank of the fold for nearly 2 miles and form an important oil-bearing bed.

There are several phases of oil accumulation in the Santa Margarita (?) of the McKittrick area. Black, hard threads and stringers of pure bitumen penetrate the shales at many places along cracks which are usually roughly parallel to the bedding. Live asphalt springs or "bubbles" carrying small quantities of gas and saline water are not unusual, especially along the anticlinal axis, and in conjunction with these the mode of growth of a brea deposit in all its stages may be studied. The impregnation of gravels, sandstones, and shales and their subsequent leaching under the influence of weather is common. The remarkable structural conditions which control the distribution of paying quantities of oil in this field, especially at its north end, will be discussed in a later chapter.

Telephone Hills area.—The northeastern base of the Telephone Hills in Ts. 30 and 31 S., R. 22 E., is defined by a normal fault which has brought the Santa Margarita (?) up against the overlying gravels and sands of the McKittrick formation. There is thus exposed on the northeast face of the Telephone Hills a block of Santa Margarita (?) diatomaceous shales, beginning at the gulch in the northeast corner of sec. 31 and passing beneath the McKittrick formation 3 miles southeast. It is nowhere more than one-half mile wide. Except at the northwest end, where conditions are locally reversed, the relations of the shales to the overlying gravels are best exposed in the gulch southwest of the pesthouse, in sec. 32.

Although there is no surficial connection between this area and that at McKittrick, the two are certainly correlated and are but the exposed portions of a single mass, the true character of which is masked by the overlying formations.

Area near Crocker Spring.—A roughly oval area of very diatomaceous massive white shale is exposed between Crocker Spring and the Santa Fe tank house along the axis of a prominent anticline which here plunges southeast. The shales of this area are well exposed in the gulches leading into that running north of the tank house, and at some points are difficult to distinguish from those which are interbedded with granitic bowldery lenses north of the tank house. The relations between the purely diatomaceous shales and the more arenaceous type with which the bowlder beds are associated is masked by the overlying McKittrick or later beds, and by the folding and minor faulting to which all the sediments have been subjected.

AREA IN MIDWAY DISTRICT.

This zone of diatomaceous shales is defined as beginning at Crocker Canyon, in sec. 18, T. 31 S., R. 22 E., although it is really a part of the last area described. It extends southeast along the Temblor Range at an elevation between 1,700 and 2,200 feet to the NE. ¼ sec. 34, T. 32 S., R. 23 E., a distance of fully 12 miles. It lies above and in apparent conformity with the Monterey shale that makes up the bulk of the range, and below the gravelly beds of the McKittrick formation, the eastward dipping beds of which define the margin of the Great Valley. The difficulty of fixing the base of the Santa Margarita (?) has already been referred to. Equal difficulty has been experienced in trying to define its upper limits, because of the intercalation of the purely diatomaceous beds, referable in themselves to the Santa Margarita (?), with coarse cobble and sandy lenses typical of McKittrick sedimentation. There is a gradual diminution of the diatomaceous beds upward in the series, and at one horizon which is persistent along the face of the mountains the McKittrick conditions are emphasized in a thick zone of very heavy granitic bowlders, with occasional great blocks several feet in diameter. This conglomerate has been assumed to be the base of the McKittrick and is so mapped and described. The main mass of the Santa Margarita(?) is a northeast-dipping monocline of creamy and pinkish diatomaceous shales, which, except toward the base, are quite free from calcareous layers. It maintains a thickness of about 900 or 1,000 feet throughout the distance, but, because of the local character of the coarser beds in the series, individual shale beds vary considerably in thickness. Local unconformities at the base of the McKittrick, resulting in overlap of the blocky loose bowlder beds upon the underlying shales, produce an appearance of greater or less thickness in the outcrops of the shales.

The following generalized section from the top downward is based upon several meanders across the Santa Margarita(?) southwest of Midway:

Section of Santa Margarita (?) formation southwest of Midway.

	Feet.
Upper portion of soft heavy-bedded diatomaceous shales, creamy to flesh-pink in color (often containing flakes of biotite mica and layers of granitic gravel and sand)	500±
Zone of gray granitic sandstone layers varying locally to gravel and conglomerates of schists and granitic rocks	100–300
Calcareous and diatomaceous shales approaching Monterey shale in appearance	200±

Near the middle of the east side of sec. 18, T. 32 S., R. 23 E., a soft brownish diatomaceous shale varying to hard nearly black flinty layers is in places heavily charged with bitumen. The shales are overlain by McKittrick granitic conglomerate, and just at the contact the joint cracks of the shale are filled with native sulphur, the crystals of which are small but well formed. Considerable gypsum, stained dark by sulphur, is found in this vicinity.

The remarkable conditions under which the shales of the Santa Margarita(?) formation and the beds transitional into the McKittrick formation must have been deposited call for some comment. It is clear that the purely organic beds, since they contain little or no material of detrital origin, could only have originated far from shore or in deep water along the face of a steep escarpment at a distance from the influence of shore currents or of inflowing waters. It is equally clear that the coarse, usually subangular granitic bowlders and blocks which lie in immediate contact with or as lenses in the organic shales indicate conditions of deposition utterly dissimilar.

Few of these blocks could have been transported by the measure of present-day evidence in the same region much more than 6 or 8 miles. Some of them, 12 or 15 feet in diameter, could hardly have been moved so far unless on a very steep gradient and by torrential volumes of water, which dumped their loads unassorted at the first convenient place. Such a condition is surely in sharp contrast with the evidence of tranquil accumulation of organic remains in the adjacent shales. This change did not happen once only, but many times, and it is difficult to conceive of the land and drainage conditions during the period. Except at one point, where a small mass of granitic rock has been faulted up into the Monterey and Vaqueros near White's camp, no granitics are exposed along the Temblor Range. The nearest known source for the bowldery lenses, then, is the Mount Pinos Range, which is fully 25 miles distant from the nearest exposures. The conformity between the Monterey shale and the Santa Margarita (?) does not suggest that the Monterey existed as a mountain range during Santa Margarita (?) time. If the granitic conglomerate was derived from the Mount Pinos Range through the agency of torrential streams, the existence of such a range as a part of the old Mount Pinos Range must, however, be assumed. There still remains the possibility of the bowlders having been carried by moving ice, which, with its load of morainal material, originated in a possibly much higher Mount Pinos Range. No striæ or other evidence of glaciation have been found on any of the blocks or cobbles in the series, however. Further knowledge of the Coast Ranges, especially in the Cuyama, Mount Pinos, and Tejon regions, will perhaps explain the problems which the Santa Margarita (?) and lower part of the McKittrick formation in the Midway district present.

It is practically certain that between the southeast extremity of the area just described and that lying south of Maricopa and Pioneer the series is continuous, although it is nowhere exposed, owing to the overlap of the McKittrick formation upon the Monterey.

AREA IN SUNSET DISTRICT.

The zone of Santa Margarita (?) in the Sunset district stretches for about 3½ miles along the hills back of Pioneer, and bears the same relation to the adjacent Monterey shale and the McKittrick formation as in the Midway district. At its northwest end the shales occupy a syncline, which flattens into a steeply northeastward dipping monocline about 1 mile west of Pioneer. The shales are diatomaceous and contain some calcareous layers. At the top of the series there are beds of sandstone, which probably are the equivalent of the granitic cobbly beds back of Midway. The following section was obtained in the gulch south of Pioneer.

Section of Santa Margarita (?) formation south of Pioneer.

	Feet.
Brea and travertine in creek bottom	10-50
Fine white organic shales with thin sandy layers	100
Brown, well-bedded, medium-grained granitic sandstones, at some points conglomeratic	200
White and yellowish limy organic shales	1,000+
	1,300±

Elsewhere in the vicinity, layers of coarse sandstone 15 to 30 feet thick, interbedded with minor amounts of white, thin-bedded, diatomaceous shale, make up a thickness of 600 to 800 feet at the top of the Santa Margarita (?). Evidences of petroleum are common along the upper horizons of this shale and are especially well developed in the base of the McKittrick formation, which rests unconformably upon them.

BITTER CREEK AREA.

The most southerly area of Santa Margarita (?) studied lies in the S. ½, T. 11 N., R. 24 W., upon both the east and west forks of Bitter Creek. The details of a part of the section in this area, obtained 5 miles southwest of Maricopa, upon the west fork of Bitter Creek, are as follows:

Partial section of Santa Margarita (?) formation on west fork of Bitter Creek.

	Feet.
Soft light terra-cotta granitic sandstones, which carry *Pecten* and *Ostrea*, indicative of Santa Margarita age, 6 feet from the top	12
Coarse granitic conglomerate, with interbedded gray and brown irregular sandstones	125
Brown and gray sand, well bedded and tending toward concretionary structure in middle	12
Granitic conglomerate and sand, larger cobbles 6 to 8 inches in diameter	12
Coarse pebbly granitic gray sand, well bedded and grading up into an overlying conglomerate bed	10

Eastward the terra-cotta granitic sandstones grade into a contorted and faulted series of pinkish to dark-brown sandstone, brownish to blackish shale, and a large quantity of shale breccia and conglomerate derived from the adjacent Monterey. The whole series is much discolored by petroleum and sulphur. Springs carrying sulphur are common a quarter of a mile above the forks of Bitter Creek.

In the hills immediately east of the forks of Bitter Creek the Santa Margarita (?) consists of soft white shale with interbedded bowldery layers and fine yellow calcareous zones. This Bitter Creek area lies within the zone of the San Andreas fault, and is consequently very greatly disturbed. No effort as yet has been made to study the detail of structure there.

AREAS EAST OF HAZELTON.

About 2 miles east-southeast of Hazelton the Santa Margarita (?) soft diatomaceous shale, thoroughly saturated with heavy oil, outcrops in two or three isolated patches. These are shown on the map as brea, owing to their important hydrocarbon contents. The shale here stands on end, is very plainly and thinly bedded, and shallow wells sunk into it have yielded commercial quantities of oil. (See pp. 191, 192 for description of development here.)

AREAS IN CARRIZO DISTRICT.

A reconnaissance in portions of the Carrizo Plain region has shown the existence of areas of Santa Margarita (?) there, and it is probable that future work in the southwest part of the region under discussion will reveal other areas.

AREA NEAR GARCÍA'S RANCH.

The gravels and sands of the Carrizo Plain at its northwestern end have been sharply trenched by Carnaza Creek in its course to San Juan River, and there are exposed in consequence a series of beds which have been identified as Santa Margarita (?). They are considerably folded and exhibit west of García's place the following section from the top downward:

Section of the Santa Margarita (?) formation near García's.

	Feet.
Alternating beds of hard and soft fossiliferous light-gray granitic sandstone....	350
Reddish sandstone and conglomerate, more or less incoherent, with an oil sand at base....	500±
Concretionary white shale at base of series or possibly of Monterey age........	50+
	900±

Between García's and San Juan River the series is prominently developed and contains at many places light sandy fossiliferous layers. Where the La Panza Valley enters that of San Juan River, fossiliferous sandstones occur in light-colored bluffs, and here some of the beds appear to have been duplicated by faulting. The Santa Margarita (?) extends southeast of García's to the corner of the township, and from a width of about 3 miles tapers off to about a mile wide at its southern extremity. The uppermost beds in this vicinity are hard fossiliferous sandstones. These rest upon less resistant gravels and form the summit of the prominent synclinal hill ending in sec. 36, T. 29 S., R. 17 E. A section in the beds of this hill is as follows:

Section of the Santa Margarita (?) in sec. 36, T. 29 S., R. 17 E.

	Feet.
Hard granitic fossiliferous sandstone....	100
Pinkish gravel....	300
Gray sandstone and gravel underlain by pinkish gravel....	600
Bed of *Ostrea titan* and *Pecten estrellanus*....	50
Basal gravelly and sandy beds....	300
	1,350

The local character of the Santa Margarita(?) formation, so well shown in the Midway region, is further emphasized by this section. Instead of the diatomaceous beds, common in the northeast flank of the Temblor Range, the formation here contains gravels and sands.

AREA NEAR VISHNU WELL.

This area extends along the west slope of the summit of the Temblor Range for about 4 miles in T. 32 S., R. 22 E. The beds here also are different from the series elsewhere. The exposure so closely resembles the huge blocky granitic conglomerate typical of the McKittrick formation to the northeast that earlier determinations placed it in that formation. Later, however, fossils of either middle or lower Miocene age were found in it, and upon lithologic and stratigraphic evidence the possibility of its belonging to the lower Miocene was eliminated. The structural conditions here, as elsewhere near the San Andreas fault, are complex, but the series appears to occupy a syncline, which has been faulted along its axis so that for a portion of its length the upthrown arm of the fold has been completely removed from the underlying Monterey.

IMPORTANCE WITH RELATION TO PETROLEUM.

Much that was said concerning the relation of the Monterey formation (lower middle Miocene) to the petroleum of the district applies equally well to the Santa Margarita(?) formation (upper middle Miocene). The organic matter contained in the latter is believed to be the source of much of the oil accumulated in the overlying McKittrick beds, and for this reason the presence of the Santa Margarita(?) or the Monterey under the McKittrick is believed to be prerequisite to the productivity of the latter. The Santa Margarita(?) shale is more likely to exhibit its petroliferous character than the Monterey, probably owing in part to its later age and less altered character. The Santa Margarita(?) is oil-bearing only in a small degree, but productive wells have been drilled into it in the eastern part of the Sunset district. Oil is also occasionally derived from shale of the Santa Margarita(?) formation in the McKittrick district. In the Devils Den district the Santa Margarita(?) overlies the oil-bearing Vaqueros sands, and a knowledge of the thickness and structure of the former is necessary in order to properly draw conclusions concerning the probabilities of obtaining oil from the latter at any particular point.

McKITTRICK FORMATION (UPPER MIOCENE).

GENERAL STATEMENT.

Unconformably above the Monterey and Santa Margarita (?) formations and flanking the Temblor Range upon both sides throughout much of the McKittrick-Sunset region lies a series of gravels, clays, and sands which have been in large part correlated with the Jacalitos, Etchegoin, and Tulare formations of the Coalinga district.[a] It has been found impracticable at this time to differentiate these formations, and whether they can ever be satisfactorily differentiated in this district is a question. Hence they have been classed together as the McKittrick formation, from the town of that name, near which (one-half mile to the south) the formation is typically exposed. As mapped in the Carrizo district the McKittrick formation may include some Santa Margarita. The formation includes practically all of the deformational beds above the Santa Margarita(?) formation, and so is widespread upon the flanks of the Temblor Range. It includes beds of upper Miocene, Pliocene, and Pleistocene age. Breaks in the continuity of the beds are largely the accidental results of erosion, and since the unit is roughly uniform throughout, there is little reason for making areal separation in describing it. Two broad separations are possible, however, one including the areas upon the northeast, the other those upon the southwest slopes of the Temblor Range, adjacent to, and in fact including, parts of the Carrizo Plain.

With the close of the Santa Margarita(?) epoch, the conditions which produced the local coarse sedimentation in that formation became more widespread and persistent. There must have been a far bolder relief in this part of the Coast Ranges than during the early middle Miocene, and it is possible that during part of the upper Miocene (McKittrick) time the range was sufficiently elevated to prevent the existence of marine conditions.

Climatic and land fluctuations produced variations in the character of the sedimentation, and there is evidence even of entire cessation of deposition locally. Broadly considered, the deposits grow finer toward the top of the series, which is evidence of the rapid degradation or subsidence of the mountains that were the source of the deposits, or else of a change in the conditions producing precipitation.

AREAS ON NORTHEAST FLANK OF TEMBLOR RANGE.

Introduction.—The most northerly exposure of the McKittrick formation is that along the Lost Hills, which lie about 12 miles east of Point of Rocks, far out in the San Joaquin Valley. A somewhat similar but less well-defined area is that beginning at Shale Point and extending southeast almost to Santos Creek, at a distance of between 3 and 4 miles from the main foothills. South of Santos Creek the beds are exposed in the foothills, and from McKittrick the area broadens so as to include, if the thin Pleistocene cover be disregarded, all of the hilly region between McKittrick, Midway, Pioneer, and Buena Vista Lake and Buena Vista Slough.

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[a] Bull. U. S. Geol. Survey No. 398, pp. 96-154.

Lost Hills area.—While the evidence is not absolutely conclusive, the Lost Hills Range, which rises about 200 feet above the surrounding plain, is believed to be an anticlinal fold of such recency that its original form, except for the erosional scorings upon the surface, has not been lost. On its northwest end there are exposed moderately hard coarse granitic sands containing shale fragments up to 2 inches in diameter. Cobbles of granitic rock were found with these sands less abundantly. The sands are stained a peculiar brownish to yellow color by sulphur, and it was noted that ignition of the sulphur, accompanied by a slight hissing sound, was produced in some places by the blow of a hammer.

Just south of this exposure, considerable gypsum exists as crusts and veinlets in the soft sandy beds, and is sufficiently abundant elsewhere to be characteristic of the lower beds exposed in the Lost Hills. Yellowish clays are interbedded with the sand at some places, but the dips are so low that no great thickness of the formation is exposed. In sec. 11, T. 26 S., R. 20 E., the summit of the ridge is double, a condition probably due to the repetition of beds upon either side of the anticlinal axis, which may lie between the ridges. The general appearance of the beds here suggests a dip of perhaps 3° upon the northeast side and of even less upon the southwest. Upon a small spur in the SW. ¼ sec. 19, T. 26 S., R. 21 E., is the "Gas Bubble," a small well-rounded knob, which is believed locally to be the result of intumescence of the salts or expansion of vapors contained in the beds. While it is true that an unusual deposit of light-brown to blackish material, resembling certain forms of hydrocarbon, exists here, there is no further evidence of anything unusual. The upper portion of the "Gas Bubble" is a horizontal bed of greenish yellow shaly clay. This is underlain by gypsiferous yellowish clays, and a careful examination of near-by outcrops of the same beds failed to show any differences in level which might indicate an uplift in the clays at the "bubble." It would appear more logical to explain the "bubble" as a residual of erosion which owes its existence to local induration.

The gravels and clays of the Lost Hills extend southeast from the highest part of the ridge for about 4 miles, and finally merge with the later nondeformational gravels of the plain.

There is no evidence by which the age of the beds exposed in the Lost Hills can be determined. They probably belong to the McKittrick formation, but may possibly be of later Quaternary age.

Antelope Hills area.—No structure whatever is evident in these hills, but their existence at such a place with the longer axis across the drainage lines, yet parallel to the major folds of the region, suggests a structural origin for them.

The material exposed is a loose gravel of dark metamorphic rocks mixed with coarse sand. Except for the facts above noted, the whole area might be as readily mapped with the late Quaternary as in the formation under discussion.

Region southeast of Media Agua Creek.—Between Media Agua Creek and the hills east of Carneros Spring there are a number of small isolated buttes of a travertine-cemented conglomerate, the pebbles and cobbles of which are largely of Cretaceous and Miocene rocks. These conglomerates rest unconformably upon both the upturned Monterey and the Santa Margarita. Some of them are certainly of Quaternary age, while others are almost as certainly much older. They have all been included in the McKittrick on the map (Pl. I). An elongated area southeast of Santos Creek and about a mile out in the plain consists of white cross-bedded sands containing shale fragments and some granitic and metamorphic pebbles. In sec. 27 the same beds contain coarse waterworn granitic pebbles in an arkose sand, and at one place on the southwest slope of the hill there is a hard limestone layer. The general dips here are at angles of 30° to 35° NE.

The local character of the formation is well exposed in a canyon on the north side of the Gould Hills. The section is as follows:

Section of McKittrick formation in secs. 2 and 11, T. 28 S., R. 20 E.

	Feet.
Very coarse wash of Cretaceous or Eocene bowlders	300±
Fragmental beds of calcareous nodules derived from Monterey, some granitic and metamorphic pebbles with sandy layers	1,700−
Clayey shale and basal conglomerate	100+
	2,100±

This is an interesting section, since it shows very clearly an unconformity high up in the series beneath the coarse material derived from the pre-Miocene rocks and another at the very base of the series where there is a strong angular nonconformity with the underlying Santa Margarita (?). In every view of the Gould Hills from the south or southwest, even at a distance of 4 or 5 miles, this unconformity is plainly visible where the later formation swings across the west end of the hills.

Salt and Temblor creeks have long been a source of travertine, and much of the flat below the mouths of these streams has been built up by the addition of such a deposit. At many places the travertine is almost pure lime; elsewhere it cements gravel and sand, and so might be classed with Pleistocene deposits. There is clear evidence at certain points in the vicinity, however, that the beds have been folded by the same stresses which have produced structures in the older rocks, and this, coupled with the difficulty of separating them from the certain McKittrick beds in the region, has determined their inclusion with the latter.

An interesting phase of the McKittrick is found on the hill about three-fourths of a mile southwest of Frazer Spring. Here fragments of Monterey shale only very slightly rounded, and the binding material also, are chalcedonized to such a degree that the matrix is almost indistinguishable from the included bits of shale. This condition is due either to local spring action or to ancient stream cementation, such as that noted at Temblor. Arnold and Anderson have discussed similar occurrences upon White Creek near Coalinga in a recent paper,[a] and to this the reader is referred.

About 3 miles east of Temblor ranch a fold, which is probably an extension of the great Temblor structure, involves the monocline of McKittrick flanking the foothills, and from the southeast corner of sec. 33, T. 29 S., R. 21 E., gives it an anticlinal structure. The fold is closely appressed and fractured along its axis, so that the natural conduits thus produced have afforded an opportunity for the escape of petroleum into the basal shale breccia of the upper beds. Deposits supposed to be of this nature are to be found on the part of the ridge almost at the center of the NW. ¼ sec. 32.

At Sheep Springs, about 1 mile south of the last-mentioned locality, the basal beds of the formation are highly siliceous and appear as a prominent faulted reef, which is particularly well exposed on the north side of the gulch where the springs are. The accumulation of travertine breccia can be readily seen at and below the outlet of the water.

On the south face of the hill, near the west line of the NW. ¼ sec. 12, T. 30 S., R. 21 E., beds of an impure limestone containing molds of *Lymnæa*, a fresh-water snail, were found. This is significant, since it indicates the fresh-water origin of this portion of the formation, which near by contains a quantity of recemented siliceous angular shale fragments.

From this point southeastward the McKittrick formation is intimately associated with the oil-bearing beds of the McKittrick district, and a close resemblance between the outcrops of this and the Santa Margarita(?) formation in portions of the field, together with the close and overturned folding and thrust faulting in the developed territory, has made the McKittrick region probably the most geologically complicated oil field in California.

Just north of the dry lake on the west line of sec. 13, T. 30 S., R. 21 E., the McKittrick rests with rough conformity upon the Santa Margarita (?), on the flanks of a steep but normal anticline, while a short

[a] Arnold, R., and Anderson, R., Conglomerate formed by a mineral-laden stream in California: Bull. Geol. Soc. America, vol. 19, pp. 147-154.

distance northeast the older beds have been overturned to the northeast and were truncated somewhat before the later gravels were deposited. The McKittrick beds consist here of rounded pebbles and cobbles of granite, quartzite, black metamorphics, and white shale, from one-half inch to 5 inches in diameter. Lenses of dark-colored sands, showing evidence of former impregnation with oil, are intercalated with the conglomerate, and the whole dips at angles of 30° to 40° NE.

In the eastern part of the SW. ¼ sec. 12, T. 30 S., R. 21 E., gravelly sands of the McKittrick formation are overturned against the Santa Margarita(?), and this exposure marks approximately the northwest limit of a condition, to be discussed later, which profoundly affects the occurrence of oil in the district. Conditions which suggest overthrust faulting between the Santa Margarita(?) and later gravelly and sandy beds have been noted 1¼ miles west of McKittrick. Near the extreme edge of the SE. ¼ sec. 19 of the McKittrick township structural conditions appear to be normal.

The contacts between the formations in these localities are sharp, but elsewhere, as in sec. 10 of the same township, near Kincaid's camp, the Santa Margarita (?) is very gypsiferous and pulverulent, so that the weathered surface almost exactly resembles that of the McKittrick. Yellowish limy cobbles and shale fragments strew the surface of both formations, so that at a distance no distinction is possible, but close examination shows that in the later series there is a great variety in texture, color, and size of the calcareous cobbles, since they are purely derivative. The smaller shale fragments of the McKittrick are usually slightly rounded, while those which have loosened in place preserve their sharp edges longer. It is usually possible to differentiate the Santa Margarita (?) and McKittrick formations where actual outcrops can be found. The McKittrick has been pretty generally removed from the Monterey and Santa Margarita(?) in the developed field, but remnants here and there indicate a former extension of the rocks between the marginal exposures south and west of McKittrick and those extending into Santa Maria Valley.

These marginal exposures do, in fact, join around the end of the southeast plunging structure near the old Belgian (now Temblor-McKittrick) Oil Company's wells. The area of McKittrick just northeast of the Santa Margarita (?) lying northwest of the wells is much faulted, and at places appears to have been fractured and then filled with sand which afterwards became heavily charged with asphaltum. Asphalt dikes of this character in sec. 27, T. 30 S., R. 23 E., were among the first of the deposits to be worked in the San Joaquin Valley. A section from the mouth of the canyon in the NE. ¼ sec 28, about one-half mile east of the Dabney (now Providence) property, toward the southwest traverses the beds of the McKittrick upon the northeast arm of the McKittrick anticline. The succession is as follows:

Section of McKittrick formation 1 mile southeast of McKittrick.

	Feet.
Soft sandy or clayey beds and coarse soft sandstones below	380
Coarse-grained pink granitic sand with numerous water-worn shale fragments up to 3 inches long	55
Soft sandstone with occasional layers of shale fragments, also brown sandstone and fine scattered shale fragments	35
Hard gray sandstone, some shale pebbles, occasionally brownish and apparently oil stained	80
Greenish and brownish clay shale with thin layers of interbedded sandstone	64
Clay shale and sandstone	18
Brown and pink coarse sandstone with shale fragments, also thin partings of shale, at some points stained by oil, and clay-filled mud cracks	145
Coarse, thick-bedded, incoherent sandstones with numerous shale fragments.	190
Largely shale and clay, alternate hard and soft layers; some sandstone and shale fragments; chocolate, pink, yellowish, and brown (color due to oil impregnation)	290
Green and brown shale with interbedded yellow sands, dark-brown and heavily charged with oil	300±
Water-worn shale fragments forming a fine conglomerate	395
	1,862±

The basal beds of the McKittrick formation in the hill one-half mile south of the Dabney Oil Company's headquarters consist of coarse sands with gravelly layers. Just above this is a bed of granitic, quartzitic, and other hard pebbles which is overlain by clay shale. Numerous *Pecten eldridgei* Arnold occur in the soft sands next to the coarse basal bed.

One-half mile southeast of the old Monarch wells, near an anticlinal axis, reddish exposures of the McKittrick formation consist of thin granitic and quartzitic pebbly beds with light-yellow and whitish clays, all impregnated with petroleum. Near the Belgian wells and along the southwest side of Shale Basin the formation is of greenish clay in which are intercalated thin layers of fine sandstone and calcareous yellow layers harder than the clay.

Some of the basal McKittrick beds are notably gypsiferous, and workings exist in nearly horizontal pulverent clayey beds in sec. 30, T. 30 S., R. 22 E., where, just south of the road, the impure gypsum has been packed for shipment as a fertilizer. No active work was in progress when the place was visited by the writers. The formation in this locality is of much the same character as that southeast of the Dabney headquarters.

In the gulch extending east from the Santa Fe tank house in sec. 17, T. 31 S., R. 22 E., the appearance of beds included for the present with the McKittrick formation is different, and along this gulch are exposed innumerable small faults, in general striking northwest and southeast, which dislocate yellowish, poorly stratified, earthy beds that resemble the finer facies of Quaternary delta material. These layers, although affected by faulting and folding, are not in conformity with the gravelly sands and clays of the usual McKittrick type. It is possible that they may be the equivalent of the heavy bowlder beds in the Gould Hills described on page 77.

The curving range of lower bare hills north and northeast of McKittrick owe their existence to the development of two well-defined anticlinal structures in the gravelly sands and the clays of the McKittrick formation. In the NW. ¼ sec. 6, T. 30 S., R. 22 E., soft yellow and grayish sandstones, at some points sulphur stained, are interbedded with thin layers of light greenish and bluish clays. Judging from the sump of an old well in this vicinity, similar and coarser granitic sands predominate to a considerable depth, the lower sands showing strong impregnation with oil.

The Elk Hills are the eastern extension of the hills just described, and are likewise a structural uplift of the McKittrick formation. The general resemblance of the beds here to one another and the low dips of the strata make a measurement of the thickness only approximate. The following section was obtained on the southwest side of Elk Hills:

Section of McKittrick formation in the Elk Hills.

	Feet.
Coarse gravel of considerable variety of rocks, maximum cobbles about 6 inches diameter	175
Soft, light yellowish-brown sandy clay with white efflorescent alkali	50
Gravel of equal parts of shale fragments and mixed colored pebbles; maximum diameter, 3 inches	50
Soft light-yellowish clays like the second bed above	40
Gravel of shale fragments and colored pebbles, the latter predominating; 4-inch pebbles maximum	100+
Soft yellowish-brown sand with occasional streaks of shale and mixed pebbles	75
Soft yellowish-brown sand with greenish drab clay stratum at base	60
Gravelly sand and clay, upper 15 feet of which is stained light purple by alkali; both sand and clay are very soft	100
	650

Although the section is crossed by a sharp fold, it is hardly more than a crinkle and does not affect the succession of the beds. The lithology of the Elk Hills is practically summed up in the section above, since, except locally, there is very slight variation in the character of the beds. Not a single fossil has been found in these hills, but the position of the beds exposed here is believed to correspond nearly with the upper portion of the McKittrick section at Midway.

The Buena Vista Hills, like the Elk Hills, are of structural origin and owe their existence to an anticlinal uplift which has folded the gravels and sands of the McKittrick formation into both sharp and low broad arches, the topographic continuity of which has been broken by streams draining into Buena Vista Valley. The beds displayed through the folding are similar to those of Elk Hills, and are fairly well exposed in the gulch running northeast across the northwest portion of T. 31 S., R. 23 E. Two anticlinal axes cross this channel almost at right angles, and at the more southerly gray clays, somewhat gypsiferous, are interbedded with yellowish gravels and whitish limy layers. The fold flanking Buena Vista Valley is steeper and shows yellowish sand with pebbly zones upon its southwest arm. About 1½ miles northeast of the gulch last mentioned, upon the north arm of the same fold flanking Buena Vista Valley, the following partial section is exposed:

Partial section of McKittrick formation on northeast flank of Buena Vista Hills.

	Feet.
Heavy conglomerate of granite, shale, and quartzitic pebbles	1,040
White calcareous layer, free from impurities	10– 20
Greenish clay and sand	450– 500
	1,500–1,560

The lowest beds of this section are probably as far down in the series as any exposed in either the Elk or the Buena Vista Hills.

In the southeast end of the Buena Vista Hills the broader geologic features are observable from the high point east of the old road in sec. 15, T. 32 S., R. 24 E. The uppermost beds here are sands and gravels, which form the rather prominent northeast face of the ridge and thence swing east and north to form the outer beds of the plunging anticline which is the main structure in these hills. Below the gravels are less conspicuous beds of yellow sand and finer pebbly material, in places stained somewhat by petroleum.

The oldest beds exposed in this vicinity lie in sec. 11 at and immediately west of the road. These are low croppings of a medium-grained sand which has been very heavily impregnated with oil. It lies exactly at the broad axis of the low but extensive anticline which affects the McKittrick formation here, and is an excellent indication of deposits of petroleum beneath. From here northward along the road the beds dip gently toward Buena Vista Valley, and, as elsewhere in this region of low dips, appear to merge with the undisturbed gravels and sands of the depressions.

An important area of McKittrick formation from 1 to 3 miles wide occurs along the northeastern base of the Temblor Range from Crocker Spring southeastward to and beyond Maricopa. Within this area are found all the productive wells of the Midway and Sunset districts, and it is believed that almost without exception the oil reservoirs drawn upon are a part of the McKittrick. One exception is the deepest sand in the St. Lawrence and adjacent wells in the central part of the Midway field; this sand is said to be of Santa Margarita (?) age. The relations of the McKittrick formation to the underlying Santa Margarita (?) have already been described (p. 75). The upper limits of the McKittrick are, at many points, indefinite, because of the close lithologic resemblance to ordinary cross-bedded or roughly assorted delta sands and gravels. Elsewhere the change from deformed to flat-lying beds marks the contact between this and the Recent deposits.

At the northwestern end of the Midway area the beds are of coarse granitic conglomerate at the base and sandy and gravelly above, with tilted and faulted beds of an earthy character east of the Crocker Spring road. Associated with these heavy basal conglomerates are white diatomaceous beds, which are locally important, as in sec. 1, T. 32 S., R. 22 E., where erosion upon an anticline and the corresponding flat syncline has exposed the shale at the surface over a considerable area. The same bed is traceable northwest for over 2 miles and southeast for about a mile upon the southwest arm of the syncline, and extends to within 1¾ miles of Midland along the anticlinal axis.

Many of the sandstone beds in the lower half of the McKittrick formation are well charged with petroleum, and it has been observed that those adjacent to the included diatomaceous shales are the richer. Many such lenses of impregnated sandstone are in the southwest portion of sec. 35, T. 31 S., R. 22 E.

A typical section of the formation is that from the Andrews well in sec. 15, T. 32 S., R. 23 E., southwest to the anticlinal axis about a mile distant. In general the following succession was obtained:

Section of McKittrick formation in T. 32 S., R. 23 E.

	Feet.
Superficial gravel dipping gently northeast and overlying beds of sand and gravel unconformably	25
Gravelly granitic sands with thin clayey layers	200
Light-green coarse and fine granitic sandstone with thin clay layers; also thin hard layers	75
Fine well-bedded yellow granitic sand with thin harder seams	100
Coarse gray sand with plentiful shale pebbles	200
Coarse and fine gray sand and greenish shales with shale pebbles	160
Gray and white sandstone with many shale pebble layers	100
Light gypsiferous sandstone with shale fragments; contains white porcelain shale layer	120
Oil sands with granitic cobbles at base, sands dark brown and coarse	50–80
Brown diatomaceous shale, strongly impregnated with oil (at anticlinal axis)	150
	1,230

The diatomaceous shales at the base of this section represent the uppermost beds that show the influence of the fluctuating Santa Margarita (?) conditions; the lowest beds of the McKittrick are exposed about three-fourths of a mile southwest of the anticlinal axis, where they bend upward on the south arm of the complementary syncline. Here the much coarser conglomerates are intercalated with fine diatomaceous shales, stained pinkish brown by petroleum.

In the vicinity of Spellacy Hill, both the anticline and the syncline that deform the McKittrick beds broaden and flatten considerably, so that the anticline has produced the dome in the developed field and the syncline the broad high flat to the southwest. The level beds exposed upon the margin of this flat are poorly stratified soft yellow sands, containing bits and pebbles of Monterey shale and of granitic rocks. In the south half of sec. 35, T. 32 S., R. 23 E., these beds begin to show the influence of deformation in a gentle northeast dip, which steepens on the knobs in the southwest quarter of the section and exposes the following beds at the base of the McKittrick, which here rests unconformably upon the Monterey.

Section of McKittrick formation in sec. 35, T. 32 S., R. 23 E.

	Feet.
Gray sand with granitic and quartzite gravel, averaging about 4 inches in diameter. The large granite blocks so characteristic of this horizon back of Midway are absent	25+
White flinty shale streaked with purple, composed of bits of opalized shale with vitreous fracture	40
Zone of sulphur-colored shale	20
Layer of gray sandstone	10
	95+

The less blocky character of the upper bed here indicates a change in the conditions which produced the heavy granitic conglomerate at the same horizon toward the northwest.

In the hills which, crescent-like, partly encircle Monarch, Maricopa, and Hazelton, the McKittrick is well exposed, and owing to the several well-defined folds which have been truncated by erosion on Bitter Creek, the succession of beds is easily seen. Because of these folds, however, a full section of the series is difficult to get. The uppermost beds in this vicinity are probably those exposed in the low hills about 2½ miles east and 2 miles northeast of Monarch, where the following succession was noted:

Section of upper part of McKittrick formation 2 miles northeast of Monarch.

Yellowish sands grading into gravelly material	300 to 500 feet.
Granitic, metamorphic, and shale pebbles in an arkose sand	
Yellowish earthy beds with calcareous streaks; some pebbles	
Fine white shale pebbles; granitic and metamorphic pebbles in lesser number; matrix soft and gypsiferous	

The bedding of these layers is very poorly preserved, but the dip appears to be 6° to 8° NE.

The broad major anticline which extends southeast across sec. 34, T. 12 N., R. 24 E., exhibits the following partial section:

Partial section of McKittrick formation in sec. 34, T. 12 N., R. 24 E.

	Feet.
Pinkish granitic conglomerate, color due to decomposition of iron-bearing minerals of the granite	100
Yellow and drab sands, drab clay layers, and hard sandstone bed near top	100
Drab clay and sand	100
	300

Due west of Maricopa the foothills are composed of thin-bedded, coarse, pebbly granitic sandstones with layers in which shale fragments are numerous. The basal beds here do not carry large bowlders, as they do farther northwest. In general, the series here has a peculiar greenish-drab color, except on those fresh exposures which may have been stained brown by oil. Relations at its contact with the underlying Santa Margarita (?) in this vicinity are usually obscure, owing to folding and faulting.

A fairly complete section of the formation in the Sunset field is based on a well log, and is as follows:

Section of McKittrick formation in the Sunset field.

	Feet.
Yellow clay	102
Conglomerate	54
Sandstone	8
Blue clay and sand	35
Yellow clay	107
Blue clay	36
Hard layer ("shell")	6
Blue clay	14
Hard layer	5
Clay and gravel	14
Blue clay and sand	194
Water sand	3
Blue clay and shale with water	102
Blue clay	12
Hard layer	4½
Blue clay	5½
Oil sand (shale and sand stringers)	23
Blue clay	23
Oil sand	5½
Shale	13
Hard layer	4½
Clay and sand	18
Oil sand	5½
Very hard layer	8
Gravel and clay	16½
Shale and oil sand	32
Bluish clay (contains fossils)	
Hard layer	
Gravel, shale, and thin hard layers	41
Hard layers	1
Oil sand	30
	923

It is evident that the well on whose log this section is founded penetrates only a portion of the series, unless there is a considerable thinning of the beds between there and Spellacy Hill, a condition for which no evidence has been found.

Two and one-half miles west of Maricopa pink to dark-brown conglomerate with maximum bowlders 1 foot in diameter overlies a clay bed, which in turn extends unconformably across the basal yellow and drab sandstones of the McKittrick, across the Santa Margarita(?), and even encroaches upon the Monterey. This lack of conformity within the McKittrick formation is characteristic and possibly marks an erosion interval at some points in the upper Miocene or Pliocene.

South and southeast of Sunset, the McKittrick formation is typically developed and the basal sandstone beds are heavily impregnated with oil. The following section, exposed in the canyon in the E. ½ sec. 28, T. 11 N., R. 23 W., indicates the lithology of the formation:

Section of McKittrick formation in sec. 28, T. 11 N., R. 23 W.

	Feet.
Sandstones, stained by sulphur and oil	60
Thin-bedded sandstone	10
Thin-bedded brown and yellow sands (color due to oil and sulphur) and thin-bedded sandstone	60
Medium-grained oil sand with shale fragments	90
Thin-bedded sandstone with some pebbly beds, at some points stained yellow with sulphur	55
Thin-bedded brown sandstone, oil impregnated	40
Conglomerate of sandstone pebbles and cobbles with maximum diameter of 18 inches	55
Oil seepage in medium-grained granitic and micaceous sand	60
Coarse gray granitic sand charged heavily with oil. Sulphur water escapes from spring in sand, but little oil accompanies it	75
Brown oil-stained and yellow granitic sand	30
Granitic sand, shale and sand pebbles with diameter of 3 inches	85
At axis of anticline flat beds of granitic sand stained yellow, and pink gypsum oil and sulphur.	
	620

The canyons both east and west of that in which the above section was made are identical with it in structure and general lithology, although the oil seepages are less marked toward the northwest. There is every reason to believe that the possibilities for oil development in the flats north of this neighborhood are good. From this locality the McKittrick formation extends eastward along the south end of the San Joaquin Valley, at least beyond the mouth of San Emidio Creek, and to a point near Grapevine Canyon, where it is well exposed in a section along Pleito Creek. It is probable that the heavy granitic gravels skirting the Tehachapi Range at the extreme south end of the valley will be correlated with this series.

AREAS ON SOUTHWEST FLANK OF TEMBLOR RANGE.

At Carter's ranch, which lies within Palo Prieto Pass at the west edge of the region studied, the McKittrick formation is well developed in a broad area which is undoubtedly a part of the deposits extending northward to the mesa country east of the Salinas Valley. This area extends southeastward along the summit and southwest slope of the range to where Bitterwater Creek cuts across the mountains at Sumner's ranch; beyond that, with the exception of two residuals on the summit and a single small doubtful area near the road 3 miles southeast of McAllister's ranch, it lies only upon the southwestern slope of the range, as far as sec. 15, T. 31 S., R. 21 E. Here gravels and sands believed to belong to the McKittrick formation are involved in the intense faulting which has pushed a small block of pre-Cretaceous granite up through all the overlying sedimentary beds and brought it into contact with late Miocene deposits at the summit of the range. Small isolated areas of gravelly and sandy deposits occur along the top of the range from here southeast to the neighborhood of Vishnu well, where a larger deposit of exactly similar nature, containing Santa Margarita fossils, is found.

It is very evident that the problem of harmonizing the difference in age between these summit deposits and those extending along the lower flank of the range from the Palo Prieto region, where the gravels are probably of McKittrick age (upper Miocene), is a difficult one. A long study of the relations in this much faulted region will be necessary before the solution can be reached; for the present it can only be stated that the McKittrick formation, particularly on the summit and west slope of the Temblor range, as drawn on the map, probably includes beds of Santa Margarita age.

The McKittrick has been traced along the margin of the Elkhorn Plain only as far southeast as sec. 27, T. 32 S., R. 22 E., although it may extend farther, and there are excellent proofs in the gulches tributary to Carnaza Creek that the series underlies the Carrizo Plain, at least in its northern portion, as a broad geosyncline. It has not been found, however, upon the southwest margin of the Carrizo Plain as a part of the deformational series. At present no data are available as to the depth or character of the filling of the Carrizo Plain at its broadest part.

LITHOLOGY OF BEDS ON WEST SLOPE.

The broad, rolling, grassy slopes of the summit of the range east of Carter's ranch is composed of gravels and grayish to greenish clays which are usually too soft to afford good exposures except at the heads of gulches or upon the steep landslide faces along the zone affected by the San Andreas fault. West of Carter's a low hill has been cut by the county road, and at this point a soft, light-colored arkose sandstone with pebbly layers is exposed. The hills on the southwest side of the Palo Prieto Pass are composed of southwestward-dipping sands and gravel in which the pebbles are of Miocene sandstone, Franciscan rocks, and white siliceous shale. Such is the character of the formation in most of the region between Carter's and Sumner's ranches. Good exposures are shown in sec. 1, T. 28 S., R. 17 E., where there are regularly bedded, thin, white, and brown to bluish clays containing some gypsum. The bedding has been locally affected by landslides. Lower in the series in the main gulch, just above the house at Sumner's ranch, considerably crushed, gravelly, and light-colored arkose sandy beds are exposed. These are stained a rich pink, probably by iron derived from the granite sand and pebbles of which the beds consist.

On the west side of the Palo Prieto Pass, just south of Sumner's and west of the road, there are bunchy exposures in the McKittrick of a calcareous travertine which appears to have developed along fractures of a much crushed sandstone containing large granite cobbles. On the opposite side of the creek are the vertical and overturned beds of the Monterey which have been faulted upward against the later formation.

The relations between the McKittrick and the earlier sediments are well exposed in this region, and particularly upon Bitterwater Creek northeast of Sumner's. The greenish clays and gravels of the lower portion of the McKittrick lie unconformably upon both Cretaceous and Franciscan, but have been faulted against the Monterey and Vaqueros except possibly at one point, where they appear to lap around the Monterey at its northern extremity.

All the broad country of rolling hills south of Sumner's consists of soft, bluish-green clays and gravels of the McKittrick, which have in general a gentle southwest dip, except along the zone of the San Andreas fault, where they are complexly involved with the shattered shales of the Monterey. Such are the conditions southeast of Wolfort's, where a much folded, probably anticlinal block of Monterey has been wedged into the gravels of the McKittrick formation, which are locally upturned by the movement. No attempt has been made to express anywhere along it the detail of this faulted contact. Step faults within the McKittrick make an estimate of its exposed thickness impossible.

The series is well exposed at and just southeast of the mouth of San Diego Creek in upturned beds of fine, bluish clays, with some layers of shaly gravel, all in striking contrast with the yellowish Monterey shale against which they have been faulted. Between there and White's camp there was a marked and sudden transition in the conditions under which the series were deposited. Instead of clays and fine sands there is a heavy granitic conglomerate interbedded in coarse sandy layers, which suggest intermittent torrential conditions much like those indicated southwest of Midway. These beds are well exposed in the canyon northeast of White's, where there is a fault which cuts off the base of the McKittrick and throws it against crushed yellow sandstones and brown carbonaceous shales supposed to be of Vaqueros age. The local succession of beds in this vicinity is as follows:

Section of McKittrick formation in the vicinity of White's camp.

	Feet.
Bluish and buff arkose sands containing rounded pebbles	900
Coarse sands containing beds of heavy granitic and schistose bowlders especially prominent at about 100 feet	2,000
Heavy granitic bowldery and blocky lenses in loose sands	800
	3,700

This section is typical of the series from here southeastward to and beyond the old Vishnu well in sec. 22, T. 23 S., R. 22 E.

Southwest of White's camp, parallel to the main range, but distant from it about a mile, are the Panorama Hills. At two points in these hills fossils indicative of the Jacalitos formation have been found, but as yet no attempt at differentiation has been made. A section across these hills, about 1 mile south of White's, is as follows:

Section of lower part of McKittrick 1 mile south of White's camp.

	Feet.
Granitic conglomerate	40
Brownish-yellow soft sand	70
Fossiliferous, slightly concretionary layer	10
Soft brownish-yellow sands	100
Fossiliferous layer	8
	228

IMPORTANCE WITH RELATION TO PETROLEUM.

The McKittrick formation is the principal oil reservoir of the developed fields of the McKittrick-Sunset region, its basal conglomerates and sand yielding practically all of the product of the McKittrick, Midway, and Sunset fields. The oil is believed to originate in the Monterey and Santa Margarita(?) formations, and at least part of it to migrate across the line of unconformity between these and the overlying porous beds of the McKittrick. In these fields the zone of impregnation varies in thickness from 200 to 1,000 feet or more above the base, most of the commercially productive sands lying within the lower 200 feet. Besides the evidences of petroleum found in the McKittrick in the developed fields, the group offers indications of oil in the Gould Hills, the Buena Vista Hills, and the region east of the developed Sunset fields. It is upon such evidence that the conclusions are based that productive wells will be obtained in the McKittrick formation in areas other than those already developed.

A study of the thickness and structure of the McKittrick is necessary before proper predictions can be made concerning the probabilities of the occurrence of and depth to oil-bearing beds at the base of this group of rocks.

UNDIFFERENTIATED MIOCENE.

Upon the southwest slope of the Temblor Range, in the center and southeast part of T. 32 S., R. 22 E. the western portion of T. 12 N., R. 25 W., and in secs. 4 and 5 of T. 11 N., R. 25 W., the relations of the Miocene sedimentaries is not clear and it has been found necessary to group them tentatively under the heading "Undifferentiated Miocene." This area is shown with a separate pattern symbol on the map (Pl. I). Within the area thus patterned it is believed that the Vaqueros, Monterey, and Santa Margarita (?) formations and the McKittrick formation are represented.

QUATERNARY SEDIMENTS.

DESCRIPTION.

To this period have been assigned the sands, clays, soils, and gravels which are the results of relatively recent erosion. Although deformational processes are even yet active in the region, at least along the San Andreas fault, it has been impossible to determine, in the short time available, whether the uppermost of the folded beds belong to the McKittrick formation or to a later Quaternary epoch. The Quaternary has therefore been tentatively made to include only such deposits as do not show the results of folding or faulting. This will exclude all except the modern stream alluvium, the fan materials skirting the range, and possibly some gravel remnants high on the slopes of some of the canyons.

In the smaller canyons the Quaternary deposits are usually thin and have been derived from the immediate drainage basin. Along the margin of the San Joaquin Valley there is the usual type of varied fan material, the result of the coalescence of detritus from a number of sources. These fans slope at slightly varying, but always very low, angles toward the Great Valley. In spite of the low slopes and flat surfaces, huge bowlders are often carried out on these fans for considerable distances from the mouths of the canyons by the mud-saturated torrents, which result from waterspouts during certain periods of the year. As illustrative of the size of some of these bowlders, of those lying on the low, flat slope of the valley edge near the road in the northeastern part of T. 28 S., R. 19 E., one lying 2 miles from the mouth of the nearest canyon is over 9 feet in diameter. In general, the material of the fans is finer the farther it lies from its source.

Probably the most important fact brought out in the investigation of the Quaternary is that, while each of the greater features of the region is of purely structural origin, they have at many points been greatly modified by erosion. Instances of this are observable in the Devils Den district, where Wagonwheel Mountain is entirely isolated by Quaternary gravels from its structural continuation in the Barton Hills, and where the prominent syncline of Sawtooth Ridge, in Antelope Valley, is cut off around its southeast end by Quaternary deposits. Many other instances of erosional modification of structures are available.

An excellent example of a somewhat different phase of Quaternary accumulation is that of the Santa Maria Valley, whose drainage area is restricted. The rainfall here is slightly greater than that on lower portions of the range, and, judging from the smooth contours of the canyons leading into the valley, especially from the west, is not of the torrential nature common in this region. Much of the shale detritus in the canyons is angular, having slid in from the sides, and the bits of rock pack together rather loosely and serve as an absorbent of the rain as it falls, allowing it to percolate into the similar, though more widespread, deposits of the Santa Maria Valley. Settlers at the mouths of some of these canyons state that only after the very hardest winter storms is there even a slight surface run-off. The main valley has thus become a natural storage reservoir, the spillway of which is a group of springs a short distance north and northwest of Maddux ranch. Successful wells have been sunk in this vicinity to take advantage of these water gravels. The Quaternary deposits of the Santa Maria Valley are probably not over 100 feet thick at their deepest points.

Another, the travertine phase of Quaternary deposition, has been previously referred to and in part described as belonging to the McKittrick formation. Many of the streams, particularly those flowing across calcareous portions of the Monterey shale, carry considerable lime in solution, and in the lower reaches of the stream courses, either after the waters have become overloaded or evaporation has become a greater factor, the lime is deposited with the wash gravels and sands to form a more or less firm conglomerate, which hardens upon exposure to the air. As the channels deepen, remnants of these conglomerates are retained at varying heights above the latest deposits. Such are the rather poorly cemented bowldery croppings lying with great unconformity upon the Monterey shale on either side of the main McKittrick road about 2½ miles southeast of Carneros Spring. Other examples of these travertine conglomerates are found in the shale basin southeast of McKittrick and in the canyons in sec. 32, T. 30 S., R. 22 E.

IMPORTANCE WITH RELATION TO PETROLEUM.

Except as a local lodgment place for asphalt and heavy oil in certain portions of the McKittrick-Sunset region, the Quaternary deposits are important economically with relation to the oil industry only as a mask covering the oil-bearing and related formations. As such, the Quaternary hinders the working out of the structure, a knowledge of which is necessary in properly forecasting the occurrence or nonoccurrence of deposits of petroleum in many localities throughout the region.

IGNEOUS ROCKS.

Besides those rocks of igneous origin already described in connection with the Franciscan formation (pp. 32–34), there are only two groups of areas of such rocks in the whole region studied. One of these, containing diabase, is on the southwest side of Carrizo Plain, near Syncline Hill, and has already been referred to in the discussion of the Monterey. It is only necessary to state further that it is of the common type of intrusives found elsewhere throughout the Coast Ranges in the Monterey and Vaqueros formations. The rock is a dark, fine-grained, rather soft diabase, which, though intrusive, is very limited in its effect upon the surrounding sedimentaries.

The other area lies upon the summit of the Temblor Range in the SE. ¼ sec. 23, T. 31 S., R. 21 E., just northwest of a lone cabin. The rock here is associated with rocks of Vaqueros (lower Miocene) age. Some of the material is rather scoriaceous, and the whole is undoubtedly a remnant of some flow which has since been almost wholly removed by erosion. A hand specimen of the rock, where fresh, shows an even medium grain and a dark greenish-gray color. The upper portion of the basalt of this area is honeycombed with cavities, some of which show secondary deposits of calcite or a yellowish crystalline deposit, the composition of which is unknown. This area, which is almost too small to map, is the only one of Tertiary igneous rock which has been found in place in the Temblor Range.

STRUCTURE.

In the foregoing discussions of the formations, various details of structure have been referred to, but on account of its importance in connection with the origin and accumulation of petroleum the structure is here more amply described.

GENERAL COAST RANGE RELATIONS.

The Temblor Range, which is the most southeasterly of the several mountain groups comprising the Coast Ranges of California west of the San Joaquin Valley, occupies a unique position with reference to the great forces controlling structural conditions in California. It is skirted along its southwest side by the great world structure line known in the United States as the San Andreas fault zone. The range projects at its southern end into the complicated country including the Tehachapi and Mount Pinos ranges, which are the topographic expression of a new set of forces brought into play at the south end of the San Joaquin Valley. In consequence of the conflict of stresses, the south end of the Temblor Range has suffered severely and a complete unraveling of the complex folding and faulting produced will be a large undertaking.

RELATION BETWEEN STRUCTURE AND TOPOGRAPHY.

There is a very close relation in the McKittrick-Sunset region between topography and structure. This preservation of structural forms is due in part to the aridity of the climate, which has prevented the obliteration of the main features, although not always of the minor folds, and in part to the recency of some of the processes which have affected the folding and faulting. Particular examples of this survival of original structure follow:

Pyramid Hills as far south as Dagany Gap form a single steep-sided anticlinal structure, which retains its form for a number of miles toward the north into the Coalinga region.

Lost Hills, which have already been described under the discussion of the McKittrick, are without doubt due to an anticlinal uplift in the originally flat surface of the Antelope Plains. They are of such recent development that erosion has not yet succeeded in destroying the original arching form.

By far the best examples in the region are the Elk Hills and the Buena Vista Hills, each of which ranges is really a single major structure with subsidiary crinkles on either arm. Seen from a distance, Elk Hills, if the very youthful but numerous drainage lines be eliminated, must present much the same appearance that it did when formed.

Syncline Hill, near the northwest end of the Carrizo Plain, is an excellent example of a syncline which has preserved its form despite the degradation of the surrounding country to a depth of 300 feet or more.

The topographic effect of faulting in the McKittrick-Sunset region is even more striking than that due to folding, especially in the San Andreas zone. Palo Prieto Pass is purely a structural depression, which, except at its southeast end, is modified but little by erosion. It shows every evidence of being a line upon which long-continued faulting has taken place. Even minor features, such as slight differences in elevation between blocks lying within the fault zone, have been preserved. All of the foothill region southwest of the Palo

Prieto Pass and its southeastern continuation, the upper course of Bitterwater Creek, has been, if not profoundly, very completely faulted, usually along lines parallel to the major displacement. In consequence there have been developed narrow tilted blocks of the upper McKittrick formation, between which have been produced elongated closed depressions, often containing ponded waters. Such faulted depressions are very common in the region. Probably the best examples of such small step faults and their corresponding tilted blocks and depressions are found at the Poso Ortega Spring, about 1½ miles southwest of Sumner's ranch.

By far the most prominent escarpment in the whole region is that which separates Elkhorn Valley from the Carrizo Plain. Although low and narrow, it is practically straight, and is the surface expression of a geologically very recent displacement upon the San Andreas fault zone. Because of its topographic prominence and structural origin, it has been called the Elkhorn Scarp.

Practically all the topographic features along the southwest slope of the range show the direct influence of the San Andreas fault. Even at a considerable distance out in the Carrizo Plain the steplike succession of blocks on the slope of the range is plainly visible.

The faults at the summit and upon the northeast slope of the range are less effective in modifying the topography, although they, too, have indirectly done their part. Faults in the Antelope Valley have undoubtedly been instrumental in giving an opportunity for more rapid erosion there. A portion of the course of Salt Creek north of Temblor ranch may also owe its origin to a fault zone.

GENERAL STRUCTURE.

As in the Coalinga district, the major structures of the McKittrick-Sunset region do not exactly parallel the Temblor Range, but cut it obliquely toward the southeast at a very low angle. The angle is sufficient, however, to give to the range an en échelon topography which is evident in such spurs as that of Shale Point, Gould Hills, Elk Hills, and Buena Vista Hills. The eastward swing of the folds is accentuated in the southern portion of the range, and is due to the greater dominance of the stresses which formed the east-west block of the Tehachapi and Mount Pinos ranges.

The long period during which deformation has been taking place in the region is amply shown in the series of marked unconformities which separate formations and in the overlaps of one series upon another. The merely local character of some of the disturbances is often evident, as at Raven Valley, where the shales of the Santa Margarita (?) rest directly upon the Cretaceous, while but a short distance north, in the Barton Hills, several thousand feet of Eocene, Oligocene (?), and Vaqueros sediments separate them. This clearly indicates a remarkable differential elevation which became equalized at the beginning of Santa Margarita (?) deposition.

The most recent general depression of the region was that during which the gravels and clays of the McKittrick formation were deposited. Judging from their presence upon both flanks of the Temblor Range, and directly upon the Cretaceous sandstones at the summit of the mountains, it is clear that a free sweep of water must have existed where the north end of the Temblor Range now is, during a period just preceding the Quaternary. The great Quaternary uplift to which in part the Sierra Nevada owes its elevation, and which marks the beginning of the present era of rapid erosion and consequent ruggedness of peak and canyon, also produced a marked change in Coast Range conditions. The deposits of late McKittrick age were upraised at least 2,500 feet and considerably folded and ruptured, especially along the margin of the uplifted block; that is, on both flanks of the Temblor Range.

A final proof of the present instability of the region is found in the existence of the San Andreas fault zone, along which movements have occurred within historic time.

STRUCTURAL DETAILS.

Some of the larger folds and faults of the region will be described briefly, although it is believed that the maps accompanying this report are sufficiently self-explanatory for the greater number of these features.

Syncline north of McGovern's ranch.—North of McGovern's ranch is a syncline in the Monterey and Vaqueros formations, with reference to which the point to be emphasized is that it is sharply truncated by a northwest-southeast fault which brings a block of serpentine directly against the end of the structure.

Raven Valley anticline.—The axis of the Raven Valley anticline, a large normal fold which involves a broad area of Tertiary and Cretaceous rocks, is occupied by intimately folded Cretaceous beds, in which the main structure is obscured. This old core has resisted the later stresses, and consequently the shales of the Santa Margarita(?), being less stolid, have responded by the production of a number of subsidiary folds upon the northeast arm of the anticline. These are particularly well developed between Bitterwater and Packwood creeks.

Santos anticline.—The Santos anticline, a fold in the Eocene southwest of Santos's lower ranch, is unimportant, except in showing that north and south faulting in this vicinity is more recent than the folding. This is clearly indicated in the offset of the axis toward the south for a short distance between two faults which extend across the Monterey well up toward the shales of the Santa Margarita(?).

Cross folds near Temblor ranch.—In the foothills immediately north of the Temblor ranch houses there are a couple of local synclines and an anticline which involves Tejon, Vaqueros, and Monterey beds. The axes of these structures radiate eastward from a point about a mile northwest of Temblor, and extend transverse to the usual trend of the folds. They are evidently the result of stresses developed along a nearly north and south line in connection with the faulting upon Salt Creek. Other folds in the vicinity have been similarly affected, particularly the Gould anticline, which is traceable along the range southwest of Carneros Spring to sec. 22, T. 29 S., R. 20 E., where it swings east and then slightly north of east for a distance of 4 miles before it resumes a southeasterly direction.

Temblor anticline.—The Temblor anticline, despite faulting upon its axis, is one of the most persistent in the region. Its axis is clearly traceable in sandstones from a point on the summit 8 miles northwest as far as the Section Six Oil Company properties, in sec. 36, T. 29 S., R. 20 E., where it plunges sufficiently to allow the Monterey shale to pass around the nose of the fold and occupy both sides of the anticline. From this vicinity southeastward the structure is less clearly developed, but it is believed that the sinuous anticline which extends through Frazer Spring into the McKittrick district is the continuation of this fold.

Sandiego anticline.—The Sandiego anticline, which, except at its southeastern extremity, lies wholly upon the southwest side of the Temblor Range, has been traced about 9 miles. It is more regular than most of the structures near the San Andreas fault zone, and is more profound, since it brings up the Vaqueros sandstone at intervals along the axis. The discontinuous character of these exposures of sandstone indicates an undulatory condition in the axis.

Folds at summit of Temblor Range.—The structurally diverse conditions of the Temblor Range are well illustrated in the region between the summit of the Temblor-Simmler road and the head of Crocker Canyon. The summit is broad here and includes sinuous anticlinal and synclinal structures which vary from normal to overturned and even recumbent positions.

Santa Maria syncline.—The Santa Maria syncline, a prominent structure, originates in the 3,900-foot knob on the summit of the range in sec. 30, T. 29 S., R. 20 E., and from a point 2 miles southeast of there to its southeastern extremity the fold has had a marked influence upon the topography. This is less evident southwest of Temblor, where the axis occupies a flat stretch just below the county road, than it is in the Santa Maria Valley, which is an original structural depression only slightly modified since by erosion. The syncline is somewhat less marked southwest of McKittrick, but probably continues for some miles farther to the southeast.

Folds of McKittrick district.—The structures which have a definite bearing on the oil accumulation in the McKittrick district will be described under the heading "Structure" in the detailed discussion of the McKittrick field (pp. 129–130).

Special structural conditions around McKittrick.—In studying the well logs of the McKittrick region, particularly in the northwestern portion of the field, it was soon found that there was a very unusual disagreement between the surface evidence of structure and that shown at depths of 300 to 1,000 feet in the well logs. Thus, while the structure in the shales of the Santa Margarita(?) formation consists at the surface of a series of closely appressed and overturned folds, the oil sands penetrated by the wells lie in a low northeast-dipping monocline. The diagrammatic section (fig. 2) shown herewith has been drawn to aid in the explanation of what appears to be a very complex structure. It is believed that every other possible explanation has been eliminated, and the following concise statement will endeavor to make clear the only hypothesis that seems to fit the facts noted.

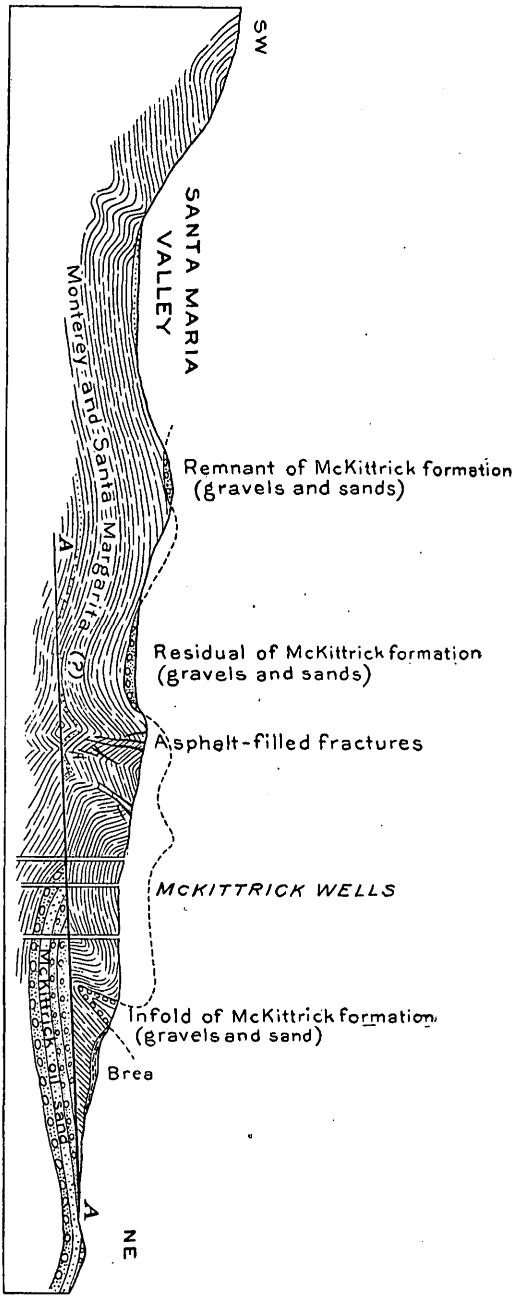

FIGURE 2.—Ideal section at north end of the McKittrick field.

In the first place, it must be assumed that the gravel and conglomeratic sands which carry the oil in this portion of the field are a part of the basal series of the McKittrick formation and that these beds were deposited unconformably upon the shales of the Monterey and Santa Margarita (?) formations. As already stated, there is plentiful evidence of such an unconformity; that the sands encountered in the wells are of McKittrick age is proved by fossils found in many of the wells penetrating these sands. Furthermore, it must be remembered that the oil gravels and sand are similar to the remnants of McKittrick which occur at many points in the McKittrick district, but that beds of similar nature do not occur interbedded in the Santa Margarita(?) or the Monterey in the McKittrick region.

At some late period, geologically speaking, the shales of the Monterey and Santa Margarita (?) formations, with their overlying McKittrick gravels, must have been faulted along a plane making a very low angle with the horizontal, as indicated in the diagram (fig. 2) on the line *A–A*, and the block to the southwest forced above and shoved across that to the northeast, so that part of the McKittrick became buried far below actually earlier shales of the Monterey and Santa Margarita (?) formations. The effect of this movement upon the shale itself was to crinkle it very sharply and produce the folds found to-day in the north end of the McKittrick field. Had this crinkling been the only result of the overthrust, the conditions, while complex, would probably be evident in the field, but in addition the structure was further complicated by two cross faults, one at either end of the overthrust. The most northwesterly of these, the Frazer Spring fault, traverses the shales of the Santa Margarita (?) just southeast of Frazer Spring, and the other, which is less apparent in the field, is believed to run in a northeast-southwest direction across the northwest portion of sec. 19, T. 30 S., R. 22 E. These two faults have effectually prevented the emergence of the gravels of the McKittrick from beneath the overthrust block of shales of the Santa Margarita (?) formation. This has been brought about in the Frazer Spring region by the upthrust of the rocks lying northwest of the Frazer Spring cross fault to an elevation sufficient to bring the McKittrick into its normal relation as an overlap upon the Monterey shale. The result, as seen in the field here, is as follows: At any point east of the Temblor ranch the gravels of the McKittrick dip at varying angles up to about 45° NE. and away from the Monterey shale, on which they rest. This condition is clearly visible to a point about one-eighth mile east of Frazer Spring, where, for a short distance, the fault has produced a confusion in the relations. About one-half mile northeast of Frazer Spring, however, the gravels of the McKittrick are found dipping directly against and beneath an abutment of the shales of the Santa Margarita (?). This point marks the first definite surface evidence of the overthrust. Unfortunately, except for a few exposures east of Frazer Spring, the northeast margin of the overthrust block lies obscured beneath the Quaternary deposits of the McKittrick Valley, until the peculiar structural conditions of sec. 19, T. 30 S., R. 22 E., connected with this overthrust are reached. In sec. 19 the two major folds (the Shamrock and Dabney anticlines) make a sharp bend toward the southwest from their normal northwest-southeast direction, and this bending, though traceable only a short distance, is very definite. A study of the well logs in this region has shown that the syncline between these two folds is also very sharply flexed and overturned, and that other structures not apparent at the surface, which extend from the northwest, butt directly into the cross folds. No explanation for this remarkable flexing is adequate unless the existence of a fault running northeast and southwest through sec. 19 be assumed. That this fault marks the southeastern limit of the overthrust condition is apparent after study of the well logs, since the group of wells immediately southeast of the fault shows that the oil sands occur on both arms of a recumbent syncline (see Pl. V) which is undoubtedly but one step removed from the complete overthrust known to exist northwest of the fault.

Folds in hills northwest of McKittrick.—Two prominent anticlines, one a section of the Gould anticline, which extends from northwest of the Temblor Valley to the Elk Hills, pass through the hills northwest of McKittrick and control the position of the geologic formations and also, to a less extent, the topography of these hills. The courses of both anticlines are sinuous and reflect the thrust movements of the fault blocks to the southwest. Toward the northern part of the hills the most westerly of the two folds is simple and has an arched top with sides dipping at angles up to 40°. Toward the southeast this fold becomes more closely compressed and possibly faulted. The easterly one of the folds is, on the whole, the more complex of the two, the beds on its flanks being steeply tilted, and in several instances crushed and faulted. Commercial deposits of petroleum occur in the McKittrick beds in these anticlines.

Folds of Elk and Buena Vista hills.—The Elk and Buena Vista hills are of very recent origin. The broadly arching anticlines to which they owe their existence have been traced as carefully as time would permit. The low angles of 5° to 10° at which the incoherent sandy and clayey beds dip makes the exact drawing of the axes with reference to the topography difficult. The two nearly parallel folds which comprise the Elk Hills are probably the southeastern continuation of the Gould Hill anticline and a parallel similar structure.

These anticlines coalesce near the end of the Elk Hills and plunge to the east beneath the San Joaquin Valley.

Similar though less continuously traceable folds are responsible for the Buena Vista Hills. About 5 miles east of the Standard Oil Company's pump station, near Midway, one of these folds begins to plunge eastward, and in so doing terminates the hills along the east line of T. 32 S., R. 24 E.

A broad syncline forms the depression between the Elk and Buena Vista hills, and upon its flanks two sharply buckled anticlines are developed. These latter folds are probably of little depth and have been produced as a result of pressure during the development of the other folds.

Crocker Spring anticline.—The Crocker Spring anticline is a good example of a plunging anticline in the older Miocene sediments. Just northwest of the road to Crocker Spring, in sec. 7, T. 31 S., R. 22 E., the fold makes a steep plunge to the southwest, but about a quarter mile farther in this direction the axis emerges in shales of the Santa Margarita (?) formation, swings toward the east for about a mile, and then again plunges, this time beneath the gravels of Crocker Creek. The unusual nature of this fold is clearly visible from the summit of the ridge in the extreme northwest corner of sec. 7.

Folds in Midway and Sunset districts.—The structures which control the accumulation of petroleum in the Midway and Sunset districts are as follows: The Midway anticline, extending from just northwest of the Santa Fe headquarters northwestward along the margin of the hills for 3½ miles; the Spellacy Hill anticline, first noted in sec. 18, T. 32 S., R. 24 E.; the Thirty-five anticline, which lies just north of Monarch and may be a continuation of the Spellacy fold; and the California Fortune anticline, which extends southeast through the hills of the McKittrick formation west of Monarch and Maricopa to a point three-fourths of a mile south of Maricopa. These folds are described in the discussion of the developed territory (pp. 143, 165).

The west wall of Bitter Creek canyon is of folded Monterey shale, no less than eight structures having been established in this region. Some of these are traceable northwest for fully 18 miles.

FAULTS.

Antelope Valley faults.—Antelope Valley is the focus of dislocations which have been long continued and profound. The course of the greatest of these displacements, an overthrust fault which has pushed the Cretaceous sandstone and shale of the north side of the valley far over the shales of the Santa Margarita (?) formation, is partly buried now by recent gravels, although a slight terrace-like shelf somewhat north of the median line of Antelope Valley may indicate the fault's position. The steep southern face of Orchard Peak and its ridge is an escarpment developed along two or more subsidiary faults within the Cretaceous. The south side of Antelope Valley is a network of faults, two systems being recognized. The older system extends northwest and southeast, approximately parallel to the folds in the sedimentaries. These older faults are offset by another system of less prominent dislocations having a general north-and-south direction. The actual line of faulting is in several places emphasized by linear clusters of springs which have risen along the fractures developed. Such are those upon the margin of the narrow belt of Franciscan just east and southeast of McGovern's ranch.

It has been found that nearly all the older systems of faults in this region, if projected, converge at or near Polonio Pass, which lies at the apex of Antelope Valley. No reason for this condition has yet been found. There is no doubt that the valley and pass form a depressed area, modified by erosion that has been accelerated in the crushed beds of the faulted zone.

Temblor fault.—Except in the McKittrick district, where faulting plays an important part in the distribution of petroleum, stresses have in general been relieved upon the eastern flank of the Temblor Range by folding. Exception to this must be made with reference to conditions noted upon the Temblor anticline. The axis of this fold is coincident with a fault which has dropped the Monterey of the southwest arm of the fold down against the Eocene of the other arm. South of the Temblor ranch the fault diverges somewhat from the axis and may extend through the obscure region near Sheep Spring and thence along the northeast slope of the hills northeast of Santa Maria Valley to join the faulted block of Telephone Hills.

San Andreas fault zone.—The San Andreas fault zone of intense displacement will be only briefly referred to here, despite its very great importance.[a] The segment of this fault zone included within the region studied extends along the southwest side of the Temblor Range for nearly 80 miles and varies from a few hundred feet to 3 miles wide. This is but a very small portion of a fault zone which has been traced uninterruptedly through California from Point Arena almost to the Salton Sea, a distance of over 600 miles. Along this zone most of the California earthquakes have originated, and it is beyond computation how long the movements had been in progress previous to historic record. These movements have so crushed, sheared, folded, and dislocated the rocks of the whole southwest side of the range that elucidation of structure and, at points, even of

[a] This fault zone is fully treated of in the Report of the Earthquake Investigation Commission upon the California earthquake of April 18, 1906, published by the Carnegie Institution of Washington, D. C., 1908.

the physical character of the rocks is very difficult. The topography produced by the latest movements in this region is unique and interesting. Low ridges on both or one side of elongated depressions, sunken areas in flat land, and great furrows along hill slopes are some of the evidences of the fracturing which occurred, as near as can be determined, in 1857. Definite evidence of horizontal movement has been found in the region, at one point of over 400 feet. Actual measurements of between 8 and 20 feet of such displacement were made at the time of the San Francisco earthquake of 1906, which occurred at and near the northwestern end of the same zone of faulting. These latest faults are mostly of the normal type and are usually parallel or convergent at very low angles.

Elkhorn Scarp is the most striking topographic evidence of the action of the San Andreas faulting. It is undoubtedly due to the dropping down of the Carrizo Plain or the elevation of the Elkhorn Valley about 200 feet. From the upper end of this scarp the fault zone extends into the Mount Pinos Mountains and thence into the San Gabriel and San Bernardino ranges.

WATER SUPPLY.

GENERAL STATEMENT.

All of the McKittrick-Sunset region, with the possible exception of a narrow zone along the highest summits of the Diablo and Temblor ranges, lies within the semiarid portion of inner California. The moisture-laden clouds from the Pacific pass over this region with little interruption by the Coast Ranges, and are precipitated as rain upon the high slopes of the Sierra Nevada far eastward. All of the run-off thus produced is taken up by the larger Sierran streams and is valuble to the agriculture of the east-side deltas. It may be said with practical certainty that not a single stream flowing into the Great Valley from its western margin is perennial. The annual precipitation ranges from 5 to 12 inches, and this is often concentrated into two or three torrential storms during the season.

One of the gravest problems, therefore, confronting those who are striving to develop the petroleum resources of this region is that of water supply, and as a possible help in the solution of this question the following notes made during the geologic study of the region are herewith offered.

SURFACE SUPPLY.

San Emidio Creek.—The nearest perennial stream which might be available to users of water in the region is probably San Emidio Creek, which heads in the San Emidio Mountains and enters the San Joaquin Valley about 12 miles east of Sunset. The normal flow of this stream belongs to the Kern County Land and Water Company, which makes use of it for irrigation upon its ranch at the mouth of the canyon. Unless unforeseen legal difficulties are in the way, however, it is believed that the storm flow of this stream, if it could be conserved, would be available, especially to the rapidly developing Sunset field. The water is undoubtedly the best to be found in the neighborhood, since its source is in a granitic region sufficiently high to be fed by the winter snows.

Buena Vista Lake.—Buena Vista Lake, the waters of which also belong to the Kern County Land and Water Company, would seem to be another source of fairly good fresh water. This lake lies 291 feet above sea level, and its waters are derived principally from Kern River. The use of this source would entail the construction of pumping plants and pressure lines sufficient to insure a lift of at least 900 feet, exclusive of friction loss. While this would involve the expenditure of a considerable sum, it would doubtless greatly simplify the present vexatious question of water supply if an arrangement agreeable to the owners could be effected.

San Juan River.—A third source which, however, is almost out of the question, is San Juan River, which flows along the southwest side of the Carrizo Plain. The water is said to be of fair quality and if properly conserved could be had in sufficient quantity for the needs of the region. The two greatest difficulties in connection with this source are its distance, between 20 and 25 miles, from McKittrick, and the obstacles which the Temblor and Caliente ranges present in the construction of pipe lines. Whether a gravity line could be built from this river to the oil fields is doubtful. No other possible surface source within a reasonable distance of any of the developed fields is known.

UNDERGROUND SUPPLIES.

In underground supplies are included such sources as might be developed from springs or wells. Unfortunately much of the spring water in the region is inferior in quality, but it is probably all suitable, with treatment at least, for boiler purposes, while distillation makes it fit for drinking purposes. The following localities are cited as affording possible opportunities for water development:

Wells in Devils Den district.—The following data concerning the water wells drilled in the Devils Den district or adjacent regions are of interest:

County water well, south line of sec. 33, T. 26 S., R. 20 E. Struck water at 45 feet; drilled to 160 feet with water all the way. Windmill connection to 130 feet, but found that the well could be satisfactorily operated by pumping from 60 feet.

Tickle well, SW. ¼ sec. 21, T. 25 S., R. 19 E. Struck water at 112 feet in a dug well. No water was encountered in wells on the low ground west of the Tickle well.

Miller well (Cesmat well), NE. ¼ sec. 35, T. 25 S., R. 20 E. Water struck at 270 feet in drilled well. Minor quantities encountered at 136 feet or 140 feet.

Water well, sec. 25, T. 25 S., R. 19 E. No depth given.

Water well, sec. 7, T. 25 S., R. 20 E. Water struck at about 60 feet.

The water in all of the above wells is more or less mineralized and is usually suitable only for stock or certain industrial purposes.

Spreckels Springs.—In the Devils Den region the most notable springs are those which were developed a number of years ago by the Spreckels Oil Company in the southeastern extremity of the Diablo Range. Several springs at the head of a canyon which flows eastward through secs. 23 and 24, T. 25 S., R. 17 E., have been enlarged and the water piped to a wooden tank near the mouth of the canyon, just above the group of camp houses of the company. The total flow of these springs does not appear to be much over a couple of inches, but the water is good and constant in supply. It is stated that over $12,000 was spent in the development of this water.

Cottonwood Springs.—A series of springs in Cottonwood Canyon, but near its mouth, just below the road between Dudley and Cholame, have apparently never been developed, and these would undoubtedly furnish several inches of water in case of need.

Alamo Solo Springs.—At about the center of sec. 2, T. 25 S., R. 18 E., the underflow of McLure Valley is brought to the surface, probably by the shale reef of the Santa Margarita (?) formation, which marks the connection between the two portions of the Pyramid Hills, in a series of slow-flowing springs which are used as a watering place by the stock of the neighborhood. Although the water is apparently inferior, being strong in Epsom salts, it is constant in flow and might be of service during preliminary developments in the region. A somewhat similar spring lying in the NE. ¼ sec. 11, is in midsummer hardly more than a seep. All of the country adjacent to this gap is more or less moist and covered with efflorescent salts, and the alkaline ground water undoubtedly lies but a short distance from the surface. Wells have been sunk in this part of McLure Valley and furnish an alkaline water which has been used with moderate success in drilling in the Barton Hills.

Springs near Annette.—A number of springs along or associated with fault zones have been found in this region. The water is usually excellent, but except in the springs about half a mile southeast of Annette post-office does not generally flow in great quantity. Those just referred to, however, have a measured flow in spring of as much as 10 miner's inches and are used for intensive irrigation upon a near-by ranch. As no oil development has yet taken place in this region, the call for use of the water of these springs is not imperative. None of them have sufficient volume to pay for transmission beyond a few miles.

Packwood Spring.—A single flow of rather strong sulphur water in sec. 8, T. 27 S., R. 18 E., is the only supply in the Tertiary rocks for a number of miles in either direction along the flank of the range. Although poor, it might serve as boiler water in case of need.

Springs on summit of range southeast of Cedar Canyon.—The summit of the Temblor Range from Cedar Canyon southeast to the Kern County line contains undoubtedly the best springs of the whole McKittrick-Sunset region, both in quality and amount of water. Of these sources Napoleon, Walnut, Los Yeguas, and Santos springs are the most important, and of these Los Yeguas probably has the greatest flow. It rises in a canyon on the McAlester ranch and flows southwestward to form a part of the headwaters of Bitterwater Creek. When visited in August, 1908, a quantity of water entirely derived from Los Yeguas Spring was flowing down the gulch. This water belongs to one of the Henry Miller properties, but is unused except for stock purposes. Walnut Spring is of the same character, but it does not appear to have quite as heavy a flow. The Napoleon Spring taken alone is unimportant as a source. It is believed that if the waters of Walnut and Los Yeguas springs could be combined they might prove valuable in the oil development upon the east flank of the range, to any part of which they could be distributed by gravity. The water of Santos Spring rises in the bottom of a canyon about 2 miles southeast of the McAlester ranch, and while good, is not great in quantity. None of these springs are being used as their importance demands.

Carneros Spring.—A basin hollowed out of the sandstones in the NE. ¼ sec. 5, T. 29 S., R. 20 E., receives a small quantity of fairly good water, which trickles slowly in from the surrounding rocks. Despite its insignificance, this spring is as well known as any in the region, since it is the only potable water near the road between McKittrick and Dudley. For years past it has been in use by the cattlemen and sheep herders of the region, and, to judge from the remarkable pictographs and pottery fragments found among the steep rocks in the neighborhood, was known for untold years by the Indians previous to the coming of the white man. The waters of another spring a mile or two southeast of Carneros might, by combination with it, give a sufficient supply for a small amount of development.

Springs near Temblor.—Springs which are said to have originated during an earthquake in the early sixties flow down the canyon of Temblor Creek. Some of these have been utilized by the ranch, but others remain undeveloped, although the Section Six Oil Company, the properties of which lie a short distance northeast of the ranch house, contemplate piping the waters of these springs to its wells.

Sheep Springs.—Several springs, locally known as "Sheep Springs," flow from beneath the travertine-cemented gravel in the canyon in sec. 4, T. 30 S., R. 21 E., and these join to make a considerable stream used for stock purposes. Judging from the amount of travertine in the vicinity, the water is highly charged with lime. So far as known this water has not been used at any of the oil wells to the east, possibly because of legal difficulties, since the springs belong to the Henry Miller Company.

Springs between Sheep Springs and Temblor.—About a mile north of Sheep Springs the McKittrick formation rests unconformably upon the Monterey shale, and at this line rise several more or less saline springs. The water is inferior both in quantity and quality, but might bear a certain amount of development. So far as known, these springs are not utilized for any purpose.

Frazer Spring.—Of a somewhat similar nature is a spring which lies just west of the McKittrick-Coalinga road in sec. 2, T. 30 S., R. 21 E., at the axis of the anticline at that point. The flow is utilized for stock, and it is doubtful if there is sufficient surplus water for any other use.

Gravels of Santa Maria Valley.—As described previously (p. 91), the gravels of the Santa Maria Valley form a natural reservoir for the storage of such run-off as falls upon the rather limited drainage basin inclosing it. Few of the canyons entering the valley show any evidence of surface flow, and it is believed that probably two-thirds of the precipitation in this region finds its way by slow percolation to gravels in the lowest part of the valley. The natural spillway of this gravel-filled depression is a spring about one-half mile northwest of Maddux ranch, but the available supply has been increased by the sinking of eight wells from 58 to 70 feet in depth. The material in all these wells seems to be a mixture of sand, clay, and small bits of shale very similar to the superficial deposits of the region. The best flow of water in these wells is to be found at a depth of 40 to 60 feet, beneath hard conglomeratic rocks which are probably travertine. While the capacity of the wells has not been measured, it is believed to be between 5,000 and 9,000 barrels a day. The water from these wells is piped about 20 miles through one 4-inch and one 8-inch pressure line and furnishes the greater part of the supply of the Midway field. It formerly retailed at Midway for 21 cents a barrel but is now much cheaper. A well belonging to the Associated Oil Company has been sunk in this same vicinity, but nearer the springs, and this supply is used in and around McKittrick. It is stated that when the wells of the Santa Fe Company are pumping in full capacity the Associated well is considerably lowered.

Hot-water well at McKittrick.—Well No. 5, sunk by the McKittrick Oil Company in the NW. ¼ sec. 18, T. 30 S., R. 22 E., has for several years past been the source of an immense quantity of warm sulphur water estimated roughly at between 60 and 80 miner's inches. At present the well is not flowing, the cause for its cessation being unknown.

Crocker Spring.—This small spring and another of a similar nature about a mile west in the same canyon are utilized only for stock purposes, but might with a certain amount of development at the springs furnish a small quantity of fairly good water for industrial or other purposes.

Stratton (Oregon-Midway) water well.—This well, the water of which is used in the Midway region and even as far southeast as Spellacy Hill, rises in a well sunk originally for oil in the northeast corner of sec. 7, T. 32 S., R. 23 E. For this region the water is good, and is said to amount to about 100,000 gallons per day, all of which is utilized. A second well was sunk by the same company a few hundred feet northeast for the purpose of developing more water, but none was obtained. No satisfactory explanation for this condition has been found, although it is possible that the water well happened to strike a fracture associated with the near-by anticlinal axis, which the later well missed. No natural sources of water have been noted between Crocker Spring and the southern limit of the region studied, unless the slow water and tar seepage just west of Maricopa is excepted.

Water wells in Sunset region.—Four or five water wells in the Sunset-Monarch region, however, are worthy of mention. Occidental No. 4 obtains its water between 1,450 and 1,550 feet deep in a series of sands. No temperature record is available, but the water is warm. The Arcola water well flows about 3,000 barrels a day of strong sulphur water, with a temperature of 120° F. The Tiger well obtains its water from a zone between tar sands at a depth between 500 and 600 feet. The Fulton well gives about 800 barrels a day from hard sands at a depth of over 1,700 feet. The well of the Northern Oil Company, described in detail on page 184, gives several thousand barrels of warm slightly saline water per day. This water occurs in an isolated sand lens at the top of zone B. All these wells except that last mentioned and the Tiger obtain their water from the sand lenses intercalated in the Miocene shales.

In the NW. ¼ and SE. ¼ sec. 13 are three water wells about which little is known except that the supply is derived from a depth of about 800 feet. Some data upon the quality of certain waters in the Sunset-McKittrick district are given by W. L. Watts.[a]

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[a] Bull. California State Min. Bur. No. 3, pp. 90 and 91.

AMELIORATION OF PRESENT CONDITIONS.

The development of the west-side oil fields of the San Joaquin Valley is being retarded at present as much by the lack of proper water supply as by anything else. The Southern Pacific Railroad Company furnishes a small and irregular supply to users at its tracks at the rate of 3 cents a barrel. This supply is hauled in tank cars from a point on Kern River about 40 miles from the fields. Water from the wells in the Santa Maria Valley belonging to the Santa Fe Railway formerly sold for 21 cents a barrel but is now delivered for much less. The water of the Stratton well is sold at 3 cents a barrel. None of these sources are at present sufficient. Any of them is liable to be shut off unexpectedly, and such conditions may be expected to prevail until some large company is willing to investigate the various sources of supply and invest sufficient capital to insure an elastic and permanent water-system for the region.

THE OIL FIELDS.

SUBDIVISIONS.

The McKittrick-Sunset region embraces three important and well-known oil districts, the McKittrick, Midway, and Sunset, and three others at present less important and practically undeveloped, the Devils Den, Temblor, and Carrizo Plain districts. In addition, the areas including the Lost Hills, Bitterwater Valley, and the Buena Vista Hills have been segregated as districts to facilitate the discussion of future development. The description of the important fields will first be taken up, after which those in which development is less advanced will be briefly discussed.

UNDERGROUND CONTOUR MAPS.

Explanation.—The contour maps of the McKittrick, Midway, and Sunset fields (Pls. II, III, and IV) show the structure and certain culture, such as towns, section and property lines, wells, and a few roads. The structure in the productive territory is indicated by contours showing the distance above (marked plus) or below (marked minus) sea level of the top of the productive oil zone (zone B of the text). The contour interval is 100 feet. By means of these maps 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 top of the productive oil zone may be approximated for a considerable part of the territory.

Use of the maps.—Suppose it is desired to find the probable depth below the surface of the top of the productive oil zone at a point in the middle of the E. ½ sec. 12, T. 11 N., R. 24 W. An examination of the map of the Sunset field (Pl. IV) will show that this point lies approximately on the underground contour line marked "−100"; that is, the top of the productive zone (zone B) is here about 100 feet below sea level. A close approximation to the elevation of the point may be had by looking up the elevation for the nearest derrick (see list, p. 194), which happens to be Golden West well No. 1, elevation 783 feet, and calculating the difference in elevation, say 20 feet lower, either by the eye or with an aneroid barometer or level; the elevation of the point in question would then be 763 feet above sea level. The distance from the surface to the top of the oil zone mentioned would, therefore, be approximately 763 plus 100 feet, or 863 feet.

Suppose it is desired to find the dip of the beds in the SW. ¼ NE. ¼ sec. 12, T. 11 N., R. 24 W. An examination of the map just mentioned shows that the beds dip a little north of east (or strike a little east of south), and that the dip is about 400 feet for one-fourth mile, or about 30 feet for 100 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 of the contours.

Basis of the maps.—The section and property lines of the McKittrick contour map (Pl. II) are compiled from the maps loaned by various oil companies in the field. The locations and elevations of many of the wells were instrumentally determined and furnished by either the Associated or the Kern Trading and Oil Company. Other elevations were approximately determined with an aneroid barometer and the locations approximated by pacing or by plane-table methods. The underground contours are based on an examination of the log of practically every well which had been drilled in this field up to November 20, 1909.

Most of the section and property lines on the Midway map (Pl. III) and many of the locations and elevations of the wells are from a map kindly loaned by the Chanslor-Canfield Midway Oil Company (Santa Fe Railway). Still other locations are from maps furnished by the Kern Trading and Oil, Associated, and Mascot oil companies, and the rest of them were found by pacing and the elevations by aneroid barometer. The underground contours are based on an examination of the logs of practically all the wells drilled in this field up to November 20, 1909. Owing to the greater irregularity of the oil zones and sands in the Midway district and the fewer and more scattered wells upon the logs of which the contouring is based, the Midway map is less accurate than those of the McKittrick and Sunset fields.

The lines and some of the locations of the wells on the map of the Sunset field (Pl. IV) were compiled from maps furnished by various companies, including the Associated, Kern Trading and Oil, and

Standard. The elevations were obtained by aneroid barometer, and many of the locations were determined either by pacing or by plane-table methods.

Difficulties of preparation and degree of accuracy.—After carefully plotting all the logs on a uniform scale it was found that the greatest obstacle to overcome in the preparation of the contour maps 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. The effort has been to delineate on the present maps all 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 most likely to be 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 said that aside from the wells of the Associated and Kern Trading and Oil companies at McKittrick, and certain of those of the Chanslor-Canfield Midway Oil Company in the Midway field, the elevations are only roughly approximate, say, to within 25 feet or less, so that an error of at least 25 feet is liable to occur on this account. 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 these fields 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 fields will compensate in a measure for the errors in detail which are to be expected in a map based on incomplete and approximate data.

The section and property lines on the contour maps, as on the general geologic map, are only approximate, and no effort was made to correct any of the inaccuracies of the government surveys.

McKITTRICK FIELD.

LOCATION.

The McKittrick field, as defined in the present report, extends from Frazer Valley, near the north line of T. 30 S., R. 21 E., southeastward for 7 or 8 miles to the northeastern part of T. 31 S., R. 22 E. It includes the low hills between the Santa Maria and McKittrick valleys and the southeastward extension of these hills as far as the northeast corner of T. 31 S., R. 22 E. The proved territory embraces an area of between 4 and 5 square miles, but future development will doubtless add to it.

GEOLOGY.

OUTLINE OF STRATIGRAPHY.

The formations involved in the geology of the McKittrick field include the diatomaceous shales of the Monterey and Santa Margarita(?) formations, the sandstones, clays, and gravels of the McKittrick formation, and Quaternary gravels, sands, clays, travertine, and asphaltum deposits.

The Monterey consists of between 3,000 and 5,000 feet of hard clay and diatomaceous shale, with which are intercalated hard, dark-brown, calcareous, concretionary layers and occasional hard, coarse, sandstone lenses. The Santa Margarita(?) formation consists of 1,500 ± feet of soft diatomaceous shale, locally silicified to chalcedony, in which are a few fine soft sandstone lenses and layers. The McKittrick lies unconformably upon the Monterey and Santa Margarita(?), and consists of nearly 2,000 feet of soft dark-colored shale, fine to coarse pebbly sand, incoherent pebbly sand and cobbly layers, and possibly, also, travertine-hardened beds. The coarser basal portion of the McKittrick is the productive oil zone of the field, the petroliferous strata being found throughout a thickness of 200 to 600 feet or more. The Quaternary deposits consist of horizontal sands, clays, and breccias, locally hardened by travertine, or locally impregnated with asphalt, forming brea. The asphaltum also impregnates the older formations near fracture zones or outcrops of the oil sands.

STRUCTURE.

The McKittrick field offers the most difficult structural problems of all the California districts so far examined. Fortunately, the writers have had the advantage of studying the logs of practically every well ever put down in the field, and without these even the very incomplete underground map (Pl. II) accompanying this report would have been an impossibility. As it is, many problems remain quite unsolved and many of the conclusions drawn are still open for discussion.

Broadly speaking, the productive McKittrick field lies on the flanks of three more or less local and highly complex folds subsidiary to the great northeast dipping monocline of the Temblor Range. Thrust faulting and overturning have so complicated the folding as to place the older beds above the younger more commonly than in their normal relation.

From the northern end of the field, in the vicinity of the Frazer Spring fault, to the faulted zone which passes northeast and southwest across the NW. ¼ sec. 19, T. 30 S., R. 22 E., the Monterey and Santa Margarita (?) formations are thrust practically horizontally northeastward for more than a mile at the point of maximum displacement over the McKittrick beds, which originally formed the northeast flank of a normal anticline. The fault crossing northwest and southeast across sec. 1, T. 30 S., R. 21 E., marks the eastern limit of this thrust as at present recorded in the beds. Figure 2 (p. 97) illustrates in a general way the conditions as they are believed to exist in the north end of the field. A crumpling and folding of the shale, in which portions of the overlying beds were infolded with the latter, accompanied the thrusting. Erosion has removed the greater part of the overlying McKittrick from the overthrust shale area, but infolded remnants of the latter beds are still to be found throughout the field. As a result of the thrust faulting the wells in the northern portion of the field usually start down in the Santa Margarita (?) formation, pass across the fault, and into the younger McKittrick oil-bearing formation.

The conditions believed to exist at the southeast end of the field are shown in Plate V. Two anticlines, the Shamrock and the Dabney, are involved in the structure here. Both are overturned, but the Dabney is normal in the northwestern part of sec. 28, T. 30, R. 22. With the exception of one or two near the western edge of sec. 19, T. 30 S., R. 22 E., the productive wells penetrate sands on the flanks of the Dabney anticline. In the eastern part of sec. 19 and the western part of sec. 20 the productive wells penetrate the normal southwestern flank, on which is a local flexure or dome (see contour map, Pl. II), while in the southeastern part of sec. 20 and the northeastern part of sec. 29 the wells penetrate the overturned flank.

The Dabney anticline is alternately normal and overturned from immediately south of McKittrick to the region of the Belgian (Temblor-McKittrick) wells, in the southeastern part of sec. 34, T. 30 S., R. 22 E. The wells in this last-mentioned locality penetrate the oil zone of the McKittrick formation on the flanks of the Dabney anticline, which is here normal.

The structure of the McKittrick Valley is, broadly speaking, synclinal, local folds of varying degrees of magnitude affecting the trough. The hills on the northeastern side of the valley are traversed by two and possibly locally by three anticlines, with domed tops and steep-dipping and sometimes faulted flanks. Wells put down on these hills strike the oil-bearing zone at depths less than the wells put down in the McKittrick Valley.

ZONE B—OIL SANDS.

The productive sands of the McKittrick district are found at the base of the McKittrick formation, unconformably overlying the diatomaceous Santa Margarita (?) and Monterey formations. The productive zone (zone B), the one shown by contour on the map (Pl. II) consists of a series of coarse conglomerates and sand layers interbedded with more or less important shale and shale partings, the whole series varying in thickness in the wells from 60 to nearly 500 feet, depending, in part at least, on the dip of the beds. In the northern part of the field zone B lies nearly horizontal and the thickness of the productive zone is usually between 100 and 240 feet; in the southern part the zone is overturned and stands nearly vertical (see Pl. V), and the wells sometimes penetrate as much as 500 feet of more or less productive sand. The sands consist largely of quartz grains, while the pebbles and cobbles are of granite, quartzite, flinty shale and hard sandstone. The sands along the southwestern edge of the productive territory are coarser than those at the south end of the field or on the flats in front of the hills, this fact accounting in a measure for the greater productivity of the wells along the foothills, which derive their oil from the bowlder sands. Shale is said to yield a little oil in some of the wells toward the south end of the field.

The sand and gravel of the productive zone (zone B) are usually poorly cemented, and generally accompany the oil from the wells in large quantities, especially when the well is new. Gas alone is sometimes powerful enough to force loose sand and cobbles from the wells, occasionally with extreme violence.

ZONE A—TAR AND GAS SANDS.

Tar and gas sands are intercalated in the shale which overlies the productive zone of the McKittrick field, as in other California oil districts studied by the senior author. This zone of minor impregnation varies greatly from well to well, clearly indicating the local character of the sand and shale strata comprising it and the restricted conditions causing the impregnation. The zone varies in thickness from 100 to 600 feet and the individual layers from a few inches to 60 feet or more. In composition the petroliferous layers are similar to the oil sands of zone B, being coarse sand generally containing pebbles and in some places cobbles. The upper sands of zone A generally carry gas or small quantities of tar, but the degree of impregnation increases downward, until near the base of the zone in many places the sands carry oil in commercial quantities. In the central portion of the field the lower part of zone A is practically continuous with the productive zone B. In the shallower wells near the northeastern corner of sec. 14, T. 30 S., R. 21 E., the gas pressure in beds at the base of zone A or on the top of zone B is extremely high.

BEDS ABOVE ZONE A.

Owing to the overturning or thrusting over of the shale it is not unusual to find the wells in the McKittrick field starting down in beds (usually diatomaceous middle Miocene) older than the oil sands penetrated at the bottom of the well. This is true particularly in the southern end of the field, where shale (usually more or less petroliferous) is penetrated all the way down to the oil sands. In the central and northern portions of the field the wells, after penetrating the shale for a distance, pass through the plane of horizontal faulting and enter the sands and clays of the McKittrick formation overlying the petroliferous zones. In a few rare instances, such as near the middle of the E. ½ sec. 19, T. 30 S., R. 22 E., and near the middle of the NW. ¼ sec. 13, T. 30 S., R. 21 E., the wells are believed to penetrate the overturned limb of the productive zone (zone B) before entering the tar and gas zone (zone A) which overlies zone B in its normal position. This case is illustrated by Plate V. Water sands sometimes occur just above zone A, especially in the wells on or near the edge of the McKittrick Valley.

BEDS BELOW ZONE B.

The strata below zone B, where it is lying in its normal position, consist almost entirely of brown shale containing scattering sandstone lenses. Where the beds are overturned the layers underlying zone B are usually coarser than the shale which normally occupies that position. Water occurs in many wells between the base of the productive sands and the shale.

WATER SANDS.

With few exceptions the wells in the McKittrick field encounter water-bearing strata at one point or another below the surface. It may be said in general that water is more abundant in the wells drilled in the McKittrick Valley or near its edge and in the small valleys, such as the one in the western part of secs. 12 and 13, T. 30 S., R. 21 E., than in the wells drilled in the hills. This statement is true more particularly as regards the waters (surface waters) in the strata above the petroliferous zones, although it is also usually applicable to the strata below the oil sands. Only in rare instances is water found within the petroliferous zones.

The first water is encountered a few feet to over 1,000 feet above zone A (200 feet to 1,300 feet above zone B) and 25 to 600 feet, and possibly more, below the surface. All of this water is highly mineralized and useless for most purposes.

Warm sulphur water is known to underlie the oil sands of zone B over at least a part of the McKittrick field, and is believed by most of the operators to underlie them in many wells that have not yet gone below the base of the productive measures. For this reason it is customary to stop drilling before reaching the base of zone B. Some wells have gone through zone B and into the brown shale below without encountering the sulphur water, which proves that the water is, in part at least, local in distribution.

The relation of this sulphur water to the production of oil is most important, for within the last four or five years the water has come to replace the oil in the product of the wells to such an extent as to jeopardize profitable operation in certain portions of the field.

That the water was not in the oil zone when drilling began is clearly attested by the records of the early wells put down in various parts of the field. It is therefore obvious that the water has been introduced into the oil sands artificially. Opinions differ as to how the water comes in and what well or wells are responsible for the menacing conditions. Some of the operators have made exhaustive studies in an effort to discover the source of the water, so that the trouble could be remedied, but so far little headway has been made along these commendable lines. It is the belief of many, and this belief is shared by the writers, that the water comes from wells that have drilled too deep and penetrated the sulphur-water sand, and that the water from this sand being under a strong artesian pressure, has passed up through the casing and out through the perforations of the offending well or wells, or else has broken through the weakened strata adjacent to the casing and reached the overlying oil sands, which it invades, with a consequent partial or complete dispersion of the oil contents.

In some wells the increase in the percentage of water in the total product has been gradual, in others it has been very rapid, and in many more the percentage often fluctuates. No well-founded explanation has so far been advanced to account for this variation in behavior in wells apparently affected by practically similar conditions.

PRODUCT.

The oil from the wells of the McKittrick field is black to brownish in color and varies in gravity from 12.5° to 24° Baumé, the last being unusually light and, so far as known, produced only by one well. At the north end of the field it ranges between 12.5° and 21° Baumé, average 15° or 16°; the variation in the central part of the field is between 12° and 24° Baumé, average 15° to 17°; the gravity of the oil in the southern end of the field is uniform and of about 18° Baumé gravity, while the gravity of oil from wells in the valley and in the hills north of the McKittrick Valley runs from 12° to 14°, or possibly a little lighter. Gas usually accompanies the oil.

PRODUCTION.

The production of the individual wells in the McKittrick field varies from 2 to 1,500 barrels of oil per day, the last being the initial production of early and unusually prolific wells. At present the production of the individual wells toward the north end of the field runs from 50 to 300 barrels per day, with an average of something over 100 barrels; that of the central portion from 20 to 1,000 barrels, with a possible average of 125 barrels; and that of the wells of the K. T. & O.-Dabney area at the southeast end of the field, 2 to 60 barrels. The wells in the Belgian-Monarch area and in the foothills north of McKittrick produce or have produced individually from 10 to over 100 barrels per day, but only two or three of them are now being operated.

METHODS.

Except a very few that still flow, all the wells in the McKittrick field are pumped. The water and oil are separated in earthen reservoirs, the water being allowed to escape through pipes tapping the reservoirs near the bottom, while the oil is conveyed from the top.

TRANSPORTATION.

Practically all of the oil is now shipped from McKittrick in tank cars over the Southern Pacific Railroad. Two 8-inch pipe lines connecting the McKittrick district with tide water are now in course of construction. One, being built by the Producers Transportation Company (controlled by the Union Oil Company), will reach the ocean at Port Harford by way of Antelope Valley, Polonio Pass, Santa Margarita, and San Luis Obispo. The other, being built by the Associated Oil Company, goes by way of the San Joaquin Valley and reaches San Francisco Bay.

LOCAL AREAS OF THE McKITTRICK FIELD.

EAST PUENTE—SAN FRANCISCO—McKITTRICK—C. J. AREA.

Location.—The area denoted by the heading above consists of the southeastern part of sec. 3, the southwestern part of sec. 2, the northeastern part of sec. 10, all of sec. 11, the southwestern part of sec. 12, the northeastern part of sec. 14, and the northwestern corner of sec. 13, T. 30 S., R. 21 E., and includes among others the following leases: Wier (Associated), Result, Graham (secs. 10 and 11), Jackson (secs. 2 and 11), Foltz (K. T. & O.), Madison, C. J. (secs. 11 and 13), East Puente, Giant (Associated) (sec. 11), Reward (sec. 11), Buena Vista (K. T. & O.), and San Francisco-McKittrick.

Structure.—The wells in this area penetrate McKittrick beds on the northeastern flank of the McKittrick anticline, over which has been faulted the older diatomaceous shales of middle Miocene age. (See fig. 2, p. 97.) This flank becomes more or less folded in the region of sec. 11, and is finally truncated by the Frazer Spring fault, visible at the surface as it cuts across from the southwest to the northeast corner of the NW. ¼ sec. 2.

How far this fault extends southwestward from its southwesternmost appearance on the surface at the Frazer Spring-McKittrick road near the middle of the west line of sec. 2, it is not possible to state, but its effect on the oil-bearing strata is exerted at least as far as the southern part of sec. 3. Near its northeastern end the downthrow of the fault is on the northwest side, while farther southwest it seems to be on the southeast side. The displacement, judging by an examination of the logs of those wells which have been drilled near the fault, is not of such maginitude as to move the oil sands either up or down for any great distance. In fact it is the belief of the writers that zone B underlies the Frazer Spring region, probably between 800 and 2,000 feet below the surface, but it is evident, from the results obtained by prospect holes, that zone B has lost nearly all of its petroleum contents in the immediate vicinity of the fault.

Zone B.—The productive oil zone, zone B, is encountered in nearly all the wells of this area drilled northeast of the line of truncation of the McKittrick anticline and southeast of the Frazer Spring fault. Its total thickness varies from 50 feet to more than 240 feet, and it consists usually of two or more individual sands separated by partings of blue clay. The average thickness of the zone for the area is about 125 feet. The sand is coarse, usually carries pebbles, and consists largely of quartz and feldspar grains. Beds carrying cobbles 1 foot or more in diameter occur in the zone, especially near its top. The pebbles and cobbles consist largely of granite with some gray sandstone, blue chert or quartzite, and black flinty shale. The sand is more or less loose and flows out with the oil when the wells are first operated, but the coarser pebbles and cobbles soon collect around the casing and act as a strainer, reducing the amount of sand that escapes with the oil. Zone B becomes less and less productive toward the Frazer Spring fault, and is said to carry water in some parts of the region of the fault and southeast of it for at least one-half mile.

Zone A.—Tar and gas sands occur above zone B in nearly all the wells of the area, especially in those in the central part of sec. 11. Little uniformity in these petroliferous sands is noticeable from well to well except that in most of them several tar and oil sands immediately overlie zone B, or else are separated from it by only a 25 to 60 foot shale parting. The tar sands occur in some of the wells as much as 300 feet above the top of zone B, although most of them occur not more than 100 feet above it. The individual sand beds in zone A vary from a few inches to over 65 feet in thickness, and consist usually of coarse quartz sand. No water sands are known to occur in zone A in any of the wells in the area.

Beds above zone A.—The beds above zone A consist of brown and blue shale and blue clay in which sand and cobble layers are sparingly intercalated. In one well a little southeast of the center of the SE. ¼ sec. 11 gravel is reported 140 to 390 feet below the surface. In other wells gravel layers from 30 feet to 65 feet through are penetrated above zone A. The gravels encountered near the surface may be accounted for as surface deposits, but it is hard to account for the gravel layers intercalated in the shale, in view of the nonoccurrence of these beds on the surface in the near-by regions, except on the hypothesis of the thrusting of the brown shales of the Santa Margarita(?) formation over the normally superjacent McKittrick beds (zone B and associated sands and shale).

Beds below zone B.—But two wells have, to the writers' knowledge, been drilled far below zone B, and these have penetrated blue and brown shale with intercalated thin, hard sand layers. No indications of oil were encountered, although water and some gas were found in three or four of the sands.

Water sands.—Water sands occur in the shale overlying zone A in practically all the wells in the area under discussion. These sands are more or less local in character, and it is often impossible to trace any connection between those of adjacent wells. They occur usually at 300 to 900 feet above the top of zone A, or 500 to 1,300 feet above the top of zone B, and at depths below the surface of 65 to nearly 600 feet. The usual depth is between 120 and 300 feet. The water sands vary in thickness penetrated from 10 to 45 feet, and consist of coarse sands, sometimes indistinguishable from the sand which carries the oil. The water from these upper sands is more or less mineralized. In one well in the northern part of the area water occurs associated with the tar sands near the base of zone A.

As disclosed by the logs, none of the productive wells in this area have penetrated the water sand, which is believed to lie below the oil zone (zone B), and for that reason water has given little trouble in the area. In one of the deeper wells along the northwestern edge of the proved productive territory water is encountered in a sand believed to be associated with or to lie just below the sands of zone B. This well was abandoned because of the water encountered in the oil zone. One of the deeper wells still farther west struck water sand at various depths in shale considerably below what is believed to be zone B (here unproductive). The water is not known to have an artesian head sufficient in any well to bring it above the surface.

The water struck at depths of 25 to less than 200 feet in the wells occupying the little valley in the western part of secs. 12 and 13, T. 30 S., R. 21 E., is believed to be surface water confined in surface wash in a basin in general coincident in extent with the valley. This surface water is undoubtedly the source of the spring in the canyon just north of the road in the SW. ¼ sec. 12. The waters in Frazer Spring and in similarly located springs in the canyons northwest as far as the Temblor ranch, in sec. 36, T. 29 S., R. 20 E., may also have their source in basins containing porous superficial wash deposits, although their occurrence may be accounted for by the peculiar structural conditions surrounding them.

Product.—The oil produced in this area is black, and varies in gravity from 12.5° to 21° Baumé. The last quality is uncommon, and is reported in but one well in the northeast corner of the NE. ¼ sec. 14. The average for the area is probably between 15° and 16°. The oil from the base of zone B in the northwestern part of the area is the heaviest found, and is viscous enough to cause trouble in some of the wells. More or less gas accompanies the oil, and is saved and used for domestic and development purposes on most of the leases. Sand is produced with the oil, especially for a short time after the wells are first operated. Practically no water occurs with the oil in this area.

Production.—The individual wells produce 50 to 300 barrels of oil per day, the average being somewhat over 100 barrels. The production is best in the southeastern portion, becoming less and less toward the northwest. This fall in production is doubtless connected with the more complicated structural conditions and faulting toward Frazer Spring. Unusual amounts of gas are produced by some of the wells. San Francisco-McKittrick well No. 11, in particular, gave a spectacular exhibition when the oil sand was penetrated by the drill. This well is high up on the flanks of the McKittrick anticline, where it would be natural to expect strong gas pressure. As soon as the well was opened into the sand the gas blew out great quantities of loose sand, pebbles, and cobbles, wrecking the derrick and strewing the ground with débris for many feet around. One of the cobbles blown out of this well was over 1 foot in diameter and weighed 33 pounds.

The "blow out" continued intermittently from 9.30 p. m. to midnight, the longest period of activity being twenty-five minutes, the periods of quiescence being about fifteen minutes. Although a good oil producer, this well still yields large quantities of gas. C. J. well No. 6, near the one just mentioned, also produces large quantities of gas.

Methods.—Most of the wells in this area are pumped, although when first drilled they usually flow more or less oil. Even after operation for some time, they can be made to flow by agitation.

Typical logs.—A typical log in the northwestern end of the area is recorded by the driller as follows:

Log of well near middle of NW. ¼ sec. 11, T. 30 S., R. 21 E.

	Feet.
Soil	60
White shale	110
Clay	120
Sand	130
Brown shale, cavy	180
Hard brown shale, cavy	225
Brown salvy shale	250
Sulphur shale	260

	Feet.
Brown shale	325
Brown hard shale	425
Brown shale, very cavy	510
Brown mud and hard shells	535
Mud (caving)	545
Brown mud and shale	575
Hard shell and salt water	585
Mud and shells	670
Brown mud and shells	740
Hard shells	750
Mud and shells	800
Loose sand, shale, and mud	850
Brown mud and shells	870
Hard shell	880
Blue sand and mud	900
Blue shale and shell (oil and gas)	908
Blue mud, shale, sand, and gravel	930
Light brown shale and oil	950
Brown mud, gravel, and shale	970
Shells and shale (strong showing of gas)	990
Gravel mixed with brown mud and shale	1,000
Blue shale (cased and cemented)	1,013
Shale with oil	1,050
Blue shale	1,100
Brown shells and sand cubes and gravel	1,125
Shells and blue shale	1,145
Brown shale (oil sand at 1,150 feet)	1,150
Very coarse (coarsest) oil sand	1,180
Fine oil sand	1,185
Shale, sands, and shells	1,215
Mud and cobbles	1,225
Hard shells, some shale	1,230
Coarse oil sand and bowlders	1,240

A log typical of the wells drilled near the middle of the area is as follows:

Log of well near center of sec. 11, T. 30 S., R. 21 E.

	Feet.
Water sand	70–75
Shale	140
Hard shell and sulphur water	145
Brown shale	215
Blue shale, sticky	260
Shelly formation	280
Brown shale	360
Shells and gravel	390
Sand and water	400
Shell, very hard	404
Brown shale	452
Sand, gravel, and water	471
Brown sticky shale	475
Shale	705
Brown sticky shale	733
Brown sandy shale	740

	Feet.
Oil sand	741
Brown shale (show of oil)	765
Blue clay	775
Brown shale	801
Oil sand, coarse, gas and sand	808
Shale, brown, sandy	811
Sand and shale	815
Oil sand and gravel	830

The log of a typical well in the group near the corner of secs. 11, 12, 13, and 14 is given by the driller as follows:

Log of well near corner of secs. 11, 12, 13, and 14, T. 30 S., R. 21 E.

	Feet.
Wash	20
Gypsum (water at 35 feet)	35
Clay and shells (at 71 feet stratum of gravel carrying much water, hard to case)	71
Shale, shells, and gravel	111
Broken shale and gravel (then sand and gravel)	150
Sticky clay (holds pipe)	168
Gravel (very bad, gets above tools)	178
Shale and clay	225
Blue clay and shale	265
Shale, hard and brittle, clay and shale (casing fell 5 feet, stopping in sticky clay, shutting off water, drove it 2 feet)	304
Water shut off in clay, but came in again	327
Water shut off in good shape in clay and shale	340½
Landed 11⅝ inches casing in sticky clay and shale	379
Shale and fine sand, carrying quite a bit of oil	421
Sticky clay	441
Clay	541
Clay and small streak of sand, carries some oil	580
Barren oil sand	599
Stray oil sand, coarse sand, and cobbles	618
Tar sand, carries some oil, hardly enough to perforate	632
Sand growing richer and better	650
Strike shell	660
Hard shell and sand; then good pay sand, oil sand	680
Oil sand and cobbles	697
Oil sand, passed through the cobbles after having 15 feet of them	712
Very good sand, shows more oil	732
Cobbles, blew up 75 feet in hole (1 foot cobbles)	734
Oil sand	735
Cobbles	739
Cobbles, rich in oil	742
Sand, rich in oil	748
Rich sand	757
Sand, coarse, rich in oil	776
Very rich streak of sand—lively—pipe followed 10 feet	780
Passed 7 feet of cobbles and sand, very lively and rich, pipe followed	800
Cobbles and gravel, very rich and lively, casing loose	816
Oil sand, rich	827
Sand, heaved up 75 feet	837
Sand, still good, heaved up	843
Quit drilling, plugged	846

REWARD—DEL MONTE—STATE AREA.

Location.—The area denoted by the heading consists of all of sec. 13, T. 30 S., R. 21 E., except the northwest corner, sec. 18, and the northwestern part of sec. 19, T. 30 S., R. 22 E., and includes the following leases: Reward No. 1, Giant (Associated) (sec. 13), Kern River, Kern Trading and Oil (K. T. & O.) (sec. 13), Del Monte (Associated), Olig Crude, McKittrick, McKittrick Consolidated, Chandler, Wilson & Bandettini (C. W. & B.), Sans Souci, Del Monte (Associated) (sec. 19), Silver Bow, and State. It contains the best producers in the McKittrick field.

Structure.—The wells in this area penetrate the northeastern flank of the McKittrick anticline, which has a low dip at the edge of the McKittrick Valley, but becomes steeper toward the axis, and is faulted off near the axis, the fault locally limiting the productive territory on the southwest. The details of the structure are shown on the map (Pl. II) and in figure 2 (p. 97).

Zone B.—Under this heading will be described the principal oil-bearing zone. In some parts of the area, notably the southeastern, the zone of oil-bearing strata is over 600 feet thick, but it is only the lower one-third of this thicker zone that is believed to be the equivalent of what is called the "oil sand" or "rich oil sand" in other parts of the area. For this reason only the lower richer sands in the region of the thicker petroliferous series will be included in zone B as here described. The distance of the top of this zone above sea level is indicated by contours on the map (Pl. II). Little regularity in the thickness of zone B is shown by an examination of the logs, owing to the extreme local variation in the sedimentation, and in part also to difference in the personal factor introduced by the drillers.

In the northern part of sec. 13, zone B consists of one well-defined and persistent sand which in some of the wells contains a shale parting at one-fourth to one-third of its depth from the top. The total thickness of the productive sand varies from 25 to a little over 250 feet, the average being about 100 feet.

In the eastern part of sec. 13 and the western part of sec. 19, zone B ranges from 40 to 180 feet in thickness, the zone sometimes being divided by one or more partings of brown shale. In the wells in the north-central part of the NW. ¼ sec. 19, the shale parting between the top portion ("first sand") and lower portion ("second sand") is 80 feet thick and carries traces of oil. Dry white sand and sand shells are also associated with the oil sand in portions of the southeastern end of the area.

In the flat, which includes the southwestern part of sec. 18, zone B varies from 8 to 150 feet in thickness and in most places, especially in the thicker portions, contains a 35-foot blue clay and sand shell parting near the top. The sands in the flat are finer grained than those in the wells to the southwest, and carry small pebbles.

The sands of zone B consist largely of material derived from granitic rocks, such as quartz and feldspar grains, and usually contain pebbles and often cobbles of granite, quartzite, and other metamorphic and plutonic rocks. Seashells (*Pecten eldridgei* Arnold) indicating that the oil sand is a part of the McKittrick formation and the same as that exposed in the hill just south of the Dabney water wells in the middle of the E. ½ sec. 29, T. 30 S., R. 22 E., are found in the wells in the northern part of sec. 13. The sand as a rule is quite incoherent, and when the gas pressure is strong flows out with the oil, often in considerable quantities.

Zone A.—Oil, tar, and gas sands of varying importance overlie the productive zone B in most of the wells of the area under discussion. In the region of the middle of the NW. ¼ sec. 13, some of these upper tar sands may be the overturned portion of the same beds that lower down in the same wells comprise the productive sands (zone B). Farther toward the southeast and out on the flat in sec. 18 the overlying tar sands are believed to represent a local coarsening of the McKittrick strata overlying the basal and most productive beds.

Near the center of the NW. ¼ sec. 13 the tar sands are encountered near the surface and range in thickness from 100 to nearly 200 feet; they are medium to coarse grained and carry heavy tar or indications of oil. About 60 feet above the top of zone B in this locality is another zone of tar sands about 100 feet thick in which bowlders are a prominent feature; gas under considerable pressure also occurs in this lower zone of tar sands.

In the north-central part of the N. ½ sec. 13 the strata above the productive zone B carry few indications of petroleum, although porous beds such as coarse sands and cobble layers are present.

Signs of petroleum and gas are encountered in the brown shale and in intercalated sand and pebbly layers above zone B in the wells in the central-southern part of the N. ½ sec. 13, and from there southeastward to the region about the northwest corner of sec. 19 the petroliferous character of zone A becomes more and more pronounced. In the region last mentioned zone A is practically continuous with zone B, carries commercial quantities of oil in some of its sands (these usually being perforated), and attains a thickness of 200 to 400 feet in the wells. It here consists of alternating sands, gravels, and shale, the two former largely predominating. One of the most common occurrences in the wells of this area and also in the area to the northwest is a coarse gravel or sand layer, at the top of zone B or base of zone A, carrying large quantities of gas under great pressure.

In the flat in sec. 18 zone A extends as much as 600 feet above zone B, and water sands often mark the top of zone A. In one well near the west line of the SW. ¼ sec. 18 a gas pocket was encountered 200 feet above the top of zone B, in which the pressure was great enough to blow 600 feet of water out of the hole and prevent drilling for several days.

Barren sand layers are intercalated with the shale and petroliferous sands and gravels in zone A, usually in its upper portion. It is hard to account for the absence of indications of hydrocarbons in these sands, especially as they are sometimes overlain and underlain by sands carrying appreciable quantities of oil or gas. A possible explanation is that these sands are parts of lenses which are completely isolated from the rest of the strata by practically impervious layers of clay.

Beds above zone A.—The beds above zone A consist largely of brown shale, more or less sandy, in which are intercalated occasional sand and cobble lenses, some of which carry water, especially on the flat.

Beds below zone B.—The beds below zone B are largely brown diatomaceous shale believed to be of Santa Margarita age. Water sands, possibly representing the very base of the McKittrick, often occur immediately at the base of the productive sand, with little parting between the two.

Water sands.—Beds of coarse material, and sand carrying mineralized or salt water, occur above the beds of zone A in some of the wells, especially those on the flat, although it must be admitted that even in this advantageous position for accumulation water is not found in all the wells, which shows the local character of the lenses carrying it.

Water under hydrostatic pressure occurs below the oil sand (zone B) in the western part of sec. 18. This water sand has been penetrated by several wells in the area, and in one notable instance, McKittrick well No. 5, has never been shut off. This well flows with a constant stream of over 70 miner's inches of warm sulphur water so charged with hydrogen sulphide gas that when once ignited the well will burn until put out by an unusual draft of air. It is the belief of most of the operators in the field that the water, which is gradually replacing the oil in many of the wells, comes from some of the wells which penetrate the bottom sand and have not had the water properly shut off.

Sand carrying salt water was encountered at about 1,600 feet in a well put down in the Santa Margarita (?) formation in the eastern part of the SE. ¼ sec. 13.

Product.—The wells in the area under discussion yield dark-brown to black oil varying in gravity from 12.6° to 18.2° Baumé. The heaviest oil is produced by the wells on the flat, the lightest by one of the wells near the northwest end of the area. In a general way the wells at the extreme northwestern end run between 16° and 17° Baumé; those in the region of the central northern part of the N. ½ sec. 13 average 15° to 16°; those just south of the last-mentioned average 16° to 17°; those in the SE. ¼ sec. 13 run between 12.6° and 16°, and those in the NW. ¼ sec. 19 average about 15.5°. The oil comes from the wells at a temperature of about 88° to 90° F. Sand accompanies the oil in most of the wells, while more or less water is found in practically all of the wells after they have been producing for some time. The percentage of water varies from well to well, and from time to time in the same well, and ranges between a mere trace in the product to practically the total. A further discussion of the occurrence of water will be found on pages 114–115.

Gas occurs with the oil in zone B and zone A, and also in sands in zone A. A particularly persistent occurrence of the gas is noted at the top of zone B or the base of zone A in many of the wells. The gas from many of the wells is saved and used for domestic purposes and for development work throughout the field. The gas pressure in one of the wells in the NE. ¼ sec. 13 was estimated as 700 pounds per square inch.

Production.—The best producers in the area are in the northern part of the NE. ¼ sec. 13. One well recently drilled here averaged over 1,000 barrels a day for over forty-two days. Still another flowed with an average of 1,500 barrels per day for three months; still another with 500 barrels per day for six months; and most of them average 150 to 300 barrels when first drilled. Under normal conditions the individual wells in the northwestern part of the area under discussion produce 50 to 200 barrels per day; under present conditions of flooding the same wells produce 10 to 100 barrels of oil.

The production of the individual wells in the eastern part of sec. 13 and the northwestern part of sec. 19 ranges from 40 to 300 barrels per day, the wells in the deeper territory usually yielding the best results. Water is beginning to affect production in this area, but not as much as farther northwest.

The wells in the flat in sec. 18 produce on an average a little over 100 barrels per day. In the fall of 1908 little trouble was caused by water in this area, but by the fall of 1909 water was materially affecting the wells, as in other parts of the field.

Methods.—All the wells in the area are pumped, except a few in which the gas pressure is strong enough to cause the oil to flow. A new type of pump, in which the rods are connected direct to a vertical cylinder over the well, has been invented by the superintendent, Mr. Ball, and used with excellent results in the Kern River lease. The separation of the oil, water, and sand is accomplished in open earthen reservoirs.

Typical logs.—The following log is typical of the extreme northwestern end of the area, where it is believed that the oil sand may possibly be doubled back over itself in such a way as to appear in the well near the surface as well as at a depth:

Log of well near center of NW. ¼ sec. 13, T. 30 S., R. 21 E.

	Feet.
Sand, gypsum, and bowlders	50
Gray sand	60
Gypsum	65
Sandy clay	80
Dry oil sand	170
Gray sand	175
Dry oil sand	195
Blue clay	200
Dry oil sand	230
Brown shale	335
Brown shale and bowlders	485
Dry oil sand	500
Brown shale	515
Bowlders	520
Brown shale	550
Bowlders	570
Blue clay	580
Dry oil sand	595
Brown shale	665
Sand and gas	690
Oil sand	908

A characteristic log of the central part of the N. ½ sec. 13 is as follows:

Log of well near center of N. ½ sec. 13, T. 30 S., R. 21 E.

	Feet.
Surface (gypsum and shale)	20
Brown shale	300
Brown shale and oil sand, sticky and heavy	364
Oil sand	445
Oil sands and bowlders	460
Blue clay and oil sand	480
Blue clay	490
Oil sand	550
Oil sand and bowlders	580
Sticky blue clay	640
Clay and shale	680
Oil sand and shale	715
Oil sand	835
Brown shale	850

A typical log of the wells in the central southeastern part of the area is as follows:

Log of well near east line of SW. ¼ sec. 13, T. 30 S., R. 21 E.

	Feet.
Shale	175
Brown shale, shell, gas, and water	450
Shale	605
Shale, some water, sandstone	625
Oil sand	631
Sand, some oil	650
Rich oil sand	665
Sand	690
Sand, carrying some oil	740
Good oil sand	785
Good oil sand, coarse	790
Light sand, some oil	805
Shale and shell	825
Coarse, rich oil sand	830
Sand, little oil	845
Coarse sand, some oil	880
Rich oil sand	910
Oil sand, layers of slate	1,106

A typical log of the wells drilled in the southeastern portion of the area under discussion is as follows:

Log of well near center of NW. ¼ sec. 19, T. 30 S., R. 22 E.

	Feet.
Gypsum	15
Asphaltum	70
Decomposed brown shale containing some oil	80
Decomposed mixture of shale containing some water	120
Soft brown shale	530
Firmer brown shale	540
Oil sand	595
Shell with occasional streak of 1 to 2 feet good oil sand	635
Sand, heavier oil	715
Lively coarse oil sand and bowlders	725
Sticky brown shale	760
Very rich oil sand (stopped)	940

A characteristic log of the wells drilled in the flat in sec. 18 is given by the driller as follows:

Log of well in W. ½ sec. 18, T. 30 S., R. 22 E.

	Feet.
Surface	160
Cavy clay	210
Blue shale	225
Shell	228
Cavy clay	250
Shell	252
Blue clay	265
Sulphur sand	290
Brown shale	292
Sandy shale	294
Blue clay	310
Water sand	318

	Feet.
Blue clay	323
Shell	330
Shale	350
Shell	355
Blue clay	390
Sandy shale	450
Blue clay	485
Sandy shale	495
Blue clay	510
Hard shell	515
Blue clay	550
Stray sand with much oil	585
Shale	630
Blue clay	640
Clay, sand, and shale	650
Shell	652
Brown clay	665
Brown shale (full of shells; carries oil)	750
Blue clay and brown shale	765
Blue clay and sand (gas)	780
Blue clay and shale	805
Brown shale and sand	840
Stray oil sand	845
Asphaltum and blue shale	900
Blue clay	930
Asphalt sand	945
Blue clay and shells	953
Hard shell	956
Blue shale	976
Oil sand	1,042
White hard sand	1,046

SHAMROCK—K. T. & O.—DABNEY AREA.

LOCATION.

The area denoted by the heading above consists of the E. ½ sec. 19, the southwestern part of sec. 20, the northeastern part of sec. 29, T. 30 S., R. 22 E., and the northwestern part of sec. 28, and includes the following leases: Giant (sec. 19), Shamrock, Western Petroleum, Giant (sec. 20), Virginia, California Standard (sec. 20), K. T. & O. (sec. 20), Twenty, Providence (formerly and better known as the Dabney), Giant (sec. 28), Vancouver, and California Standard (sec. 28), including the old Spencer lease.

The complicated structure in this part of the field renders it desirable for purposes of description of the detailed geology of the wells to divide the area under discussion into two subareas. The first will include the Shamrock, Virginia, Western Petroleum, and Giant wells. The second includes the K. T. & O. and the Providence and wells southeast of the latter in sec. 28.

STRUCTURE.

Two overturned, compressed, and possibly faulted anticlines, on the flanks of one of which is a local flexure, are involved in the structure of this area. The overturning has been toward the northeast, and the planes of the respective axes slope toward the southwest, and consequently the axes of the folds appear at the surface northeast of the points where the same axes are penetrated by the wells. The axis of the anticline, which is here called the Shamrock anticline, may be traced from a little north of the southeast corner of sec. 38 in a northwesterly direction to near the center of the NW. ¼ of the same section. It is impossible to determine the exact position of the axis in the distorted shales, but its approximate position may be calculated from the two parallel contacts between the shales of the Santa Margarita(?) and the sandstone of the McKittrick, which are believed to lie equidistant from the axis on either side. The axis through here is marked by tar springs. It passes westward from the center of the NW. ¼ sec. 28 between the sandstone hills on either side of the Dabney water wells, near the middle of the NE. ¼ sec. 29, then swings northwest and passes approximately through the northwest corner of sec. 29. The course of the anticline through the NW. ¼ sec. 29 is marked by a series of tar seepages in the shale. The trace of the Shamrock anticline through sec. 19 is sinuous; it enters the section at the southeast corner, passing northwestward to near the center of the SE. ¼, then swings north to a point near the center of the NE. ¼ sec. 19, where it again turns to a northwest trend, passing out of the section near the middle of the north line of the section. The shales of the Santa Margarita(?) are exposed along the axis of the anticline throughout its whole extent, as described, but the unconformably overlying McKittrick formation (oil sand) is usually exposed close by on the flanks.

The Dabney anticline starts in the shale area in the NW. ¼ sec. 28, passes westward into the northern part of the NE. ¼ sec. 29, swings to a northwest trend to the center of the SW. ¼ sec. 20, thence northward and northwestward across the southwestern corner of the NW. ¼ sec. 20, and finally into the NE. ¼ sec. 19. The trace of this anticline also is marked by tar springs and brea deposits. It is overturned on the surface only northwest of the eastern part of the SW. ¼ sec. 20, although the well logs indicate that the steep southeast dips exposed at the surface in the lowest McKittrick layers (oil sands) in the southern part of sec. 20 bow under to a steep southwest dip not far below the surface.

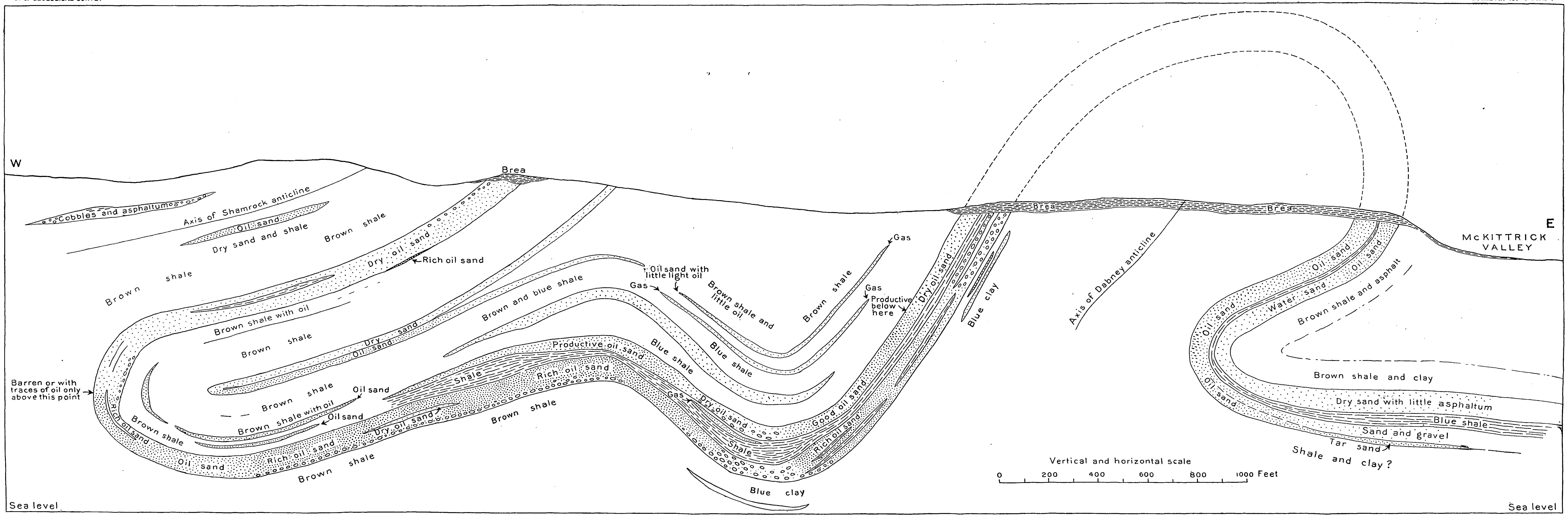
The Shamrock and Western Petroleum well logs disclose an anticlinal flexure on the southwest flank of the Dabney anticline. It is in the apex of this minor anticline that Shamrock No. 3 is drilled, and it is its position relative to this anticline that is believed to account for the unusual amount of gas and oil produced by this well.

The syncline between the Shamrock and Dabney anticlines is closely folded in the southeastern part of its course, but widens a little in the SW. ¼ sec. 20. It contains infolded sands of the McKittrick, which form the resistant east-west ridge through the center of the NE. ¼ sec. 29. In the eastern part of sec. 19 and the western part of sec. 20 the same sands are less sharply squeezed, though overturned.

SHAMROCK-VIRGINIA SUBAREA.

Zone B.—Zone B in the subarea denoted above dips southwestward, for the most part occupying the flexed southwestern flank of the Dabney anticline. The overturning of the Shamrock anticline has folded zone B back over itself (see Pl. V) beginning at a point a short distance southwest of Giant No. 51 and Shamrock No. 8, so that all wells between the line of folding and the outcrop of the oil sand (which occurs on the hill in the northern part of the NE. ¼ sec. 19) pass through zone B twice. Zone B varies in the thickness penetrated by the wells from 100 to 230 feet, being thicker in the shallower wells, where the dip of the strata is believed to be steeper than toward the bottom of the syncline, where the dip is less. The sand is coarse and consists largely of quartz grains; it becomes pebbly and finally full of large cobbles toward its base, although cobbles occur at various points throughout the zone in certain of the wells. In some of the wells one or more shale partings occur in the zone, but these are usually of minor importance. There is great variation from well to well as regards what portions of the zone are most productive. In one well the upper portion may be the richest, in an adjacent well the lower. The latter case appears to be the more common. Water occurs below zone B, especially in the syncline between the Shamrock and Dabney anticlines, but is separated from the oil sands by enough clay to permit the landing of the casing after zone B has been passed through.

Zone A.—Zone A includes those beds above the more important productive sands (zone B) which carry more or less gas, oil, or tar. As so defined, it would include the same beds that are described under zone B in those wells where zone B has been folded back over itself by the overturned Shamrock anticline. The overturned part of zone B varies in thickness in the wells from about 150 to 270 feet, and is more or less productive in those wells striking it at 300 feet or more from the surface. In wells passing through zone B within 300 feet of the surface it is usually reported in the logs as "dry surface formation," and consists of coarse sand, pebbles, and cobbles. Isolated lenses of sand carrying traces of oil and gas occur in the shale of the Santa Margarita(?) formation 200 to 500 feet strati-



HYPOTHETICAL SECTION ACROSS SOUTH END OF McKITTRICK FIELD.

graphically below zone B (but where overturned, occurring above it in the wells). Oil and tar sands occur in the McKittrick formation 50 to 400 feet above the top of zone B. A rather persistent layer, varying from 25 to 30 feet in thickness and sometimes carrying a parting near the middle, occurs at about 600 feet above zone B. This sand is said to carry light oil in places. Another lens or layer from 20 to 70 feet thick occurs in some of the wells about 400 feet above zone B. Most of the wells report traces of oil and gas or asphaltum throughout most of the finer grained formations from a few feet below the surface to the top of zone B; the hydrocarbons are too widely disseminated in this zone, however, to be of commercial importance. Just above zone B is a fine sand which is often described by the driller as "putty sand." Alternating hard and soft oil-bearing shale beds lie above the "putty sand" and are called "coffee shales" because of the resemblance of the broken-up material to coarse ground coffee. The "coffee shale" varies in thickness from 500 to over 1,000 feet as penetrated by the wells. Oil-bearing brown shale lies above the "coffee shale."

Water sand.—Water occurs in some of the wells above zone B, being struck at various depths from 140 to 600 feet below the surface. Sometimes it occurs above and sometimes below the brown oil-bearing shale of the McKittrick. It is highly mineralized, but so far as known is not under enough head to bring it to the surface. Water also occurs beneath zone B in those wells which have penetrated far below the oil horizon. Some of the wells, however, even in the syncline, have gone 100 feet below the base of zone B and not encountered water. This indicates that the water occurs in local lenses.

Product.—The highest grade of oil produced in the McKittrick field comes from the wells of this subarea. It is brownish to blackish and varies in gravity from 14° to 24.3° Baumé, the last very unusual. The average is between 18° and 21°.

The 14° gravity oil is said to come from zone B in a well in the southeastern part of the area, in which the oil from the shales above is of 20° Baumé gravity. Large quantities of gas and considerable sand are produced with the oil, especially in the best wells. The sand is more troublesome at first, becoming less and less so as the gas pressure diminishes and the finer material is removed, and the coarser material concentrates around the casing as a strainer for the oil. The temperature of the oil as it comes from the wells is about 82° F.

Production.—The individual daily production of the wells of this subarea varies from 20 to over 500 barrels. One well had an initial production said to have been over 1,500 barrels per day, and to have kept this up for nearly two years. The average of the better producers is between 80 and 200 barrels per day. With the exception of Shamrock No. 3, which penetrates the top of the local anticlinal flexure on the southwestern flank of the Dabney anticline, all the best producers strike zone B at about 1,000 feet or deeper.

Methods.—The productive wells in this subarea vary in depth from about 850 to over 1,800 feet. With the exception of two or three flowing wells, the producers are pumped. The sand is removed from the oil by settling in long, slightly tilted troughs.

Typical logs.—A typical log of the northwestern end of the area, in which zone B is folded back over itself, is as follows:

Log of well in northern part of SE. ¼ sec. 19, T. 30 S., R. 22 E.

	Feet.
Surface formation	20
Blue clay	100
Brown shale	200
Shale and sand	215
Hard shell	218
Slaty rock and oil sand	248
Oil sand	280
Dry sand and shale	360
Brown shale	550
Oil sand	571
Hard shell	585
Oil sand	640
Brown shale and oil	698
Hard shell of brown shale	704
Brown shale with oil (formation getting hard)	1,045
Brown shale mixed with oil sand	1,140
Oil sand	1,155
Brown shale	1,165

A log of one of the deeper wells, in the southeastern part of the subarea, which starts down on the outcrop of the oil sand, where it is doubled back over itself, is as follows:

Log of well in the SW. ¼ SW. ¼ sec. 20, T. 30 S., R. 22 E.

	Feet.
Surface wash and brown shale	150
Rich oil-bearing brown shale	180
Gravel and bowlders	190
Rich oil-bearing brown shale (at this depth a little water was encountered)	525
Oil-bearing brown shale (alternate hard and soft strata, gradually less oil bearing)	1,005
Brown mud or exceedingly fine sand, very sticky, and called "putty sand"	1,245
Fine-grained oil sand	1,270
Gravel and bowlders	1,279
Coarse-grained oil sand	1,345
Bluish putty sand	1,350

K. T. & O.–DABNEY SUBAREA.

Zone B.—Zone B in this subarea consists of the sand and conglomeratic beds at the base of the McKittrick formation which immediately overlie the soft, oil-impregnated diatomaceous brown shale of the Santa Margarita(?). In the proved productive northwestern part of the subarea the Dabney anticline is slightly overturned, becoming more so as the anticline passes to the southwest through the brea deposits in front of the hills west of McKittrick. (See Pl. V.) The wells, therefore, to reach the oil zone, start downward in the brown shale of the Santa Margarita(?) and enter the base of the oil zone. One of the wells near the south line of the SE. ¼ sec. 20 passes through zone B into the younger beds of the McKittrick, and then enters again what is believed to be the same bed (zone B) where it turns outward to its normal position under the flats. Where zone B is penetrated by the productive wells it dips very steeply, and for that reason its real thickness is greatly exaggerated by the distances through which the wells have to go in penetrating it.

As recorded in the well logs zone B consists of an alternation of 10 to 40 foot oil sands and 3 to 20 foot beds of blue shale or hard barren sand. Where the overthrust has been greatest, as in the eastern part of the SW. ¼ sec. 20, the distance through which the wells penetrate the zone is from 60 to 200 feet. Farther southeast, in the K. T. & O. and Dabney region, the wells penetrate about 200 feet to over 500 feet of more or less productive measures. The sand is more or less incoherent, consists of medium to coarse quartz grains, and often carries pebbles and cobbles of considerable size. The shale associated with the sand is said to yield oil in some places.

Zone A.—The brown shale overlying the oil sand in the wells (but in its normal position below zone B) contains more or less oil in the joint cracks. In fact the trace of the anticline through the strata is usually marked by surface seepages of tar or heavy oil which has passed upward through the cracks in the broken-up portions of the shale.

Beds below zone B.—The wells after passing through zone B enter brown shale, which is believed to be that associated with and normally above the oil sand (zone B) in the McKittrick formation. The deepest well but one (see log, p. 135) sunk in this subarea penetrated this brown shale of the McKittrick for nearly 500 feet below zone B, and then passed into dry or asphalt sand, believed by the writers to be zone B in its normal position. (See fig. 2.) This zone of sand was a little over 200 feet thick and carried a little heavy oil at the bottom. Below this sand was broken shale again, this believed to be true brown shale of the Santa Margarita(?), the same as that appearing above the oil sand in the overturned areas. Water was encountered at about 300 feet below the base of zone B. A well recently drilled by the Providence Oil Company in the knoll west of the main road leading from McKittrick southeast to the Midway district is said to have penetrated brown shale from the surface to a depth of over 3,000 feet. The shale here is standing practically vertical.

Water sands.—Water occurs in some of the wells above the oil sand and is believed to occur below it in practically all the wells, though for obvious reasons most of the wells are stopped before entering the water-bearing zone. In those wells which have penetrated the water sands below zone B ("bottom water"), 60 feet of water-bearing strata are reported. Efforts have been made to shut this water off, for it is the opinion of some of the operators that the water which is now becoming a menace to this part of the field is "bottom water" and comes from the wells in which the underlying water sands were penetrated. It is almost superfluous to state that unless this condition of flooding is checked the whole of zone B will eventually be rendered unproductive. At present the yield of the wells varies from 1 per cent to 95 per cent water, and in one or two instances water is said to have entirely replaced the oil in the wells. Water for development purposes is produced in shallow wells in the southern part of the NE. ¼ sec. 29.

Product.—The product of the wells in this subarea is a dark-colored oil of about 18° Baumé. Gas accompanies the oil and more or less water is also pumped with it. Most of the wells yield more or less sand, said to be more in proportion to their yield of oil than is produced in many of the wells to the northwest.

Production.—The wells in this subarea vary in production from 2 to 60 barrels of oil per day. No regularity in variation in production is noted, the yield apparently depending on local conditions of the strata and the manipulation of the well.

Methods.—The wells vary in depth from about 400 to 600 feet, although one well was drilled to a depth of nearly 1,500 feet without, however, discovering productive sands below those encountered between 200 and 400 feet. Another well drilled in the brown shale a short distance southwest of the productive belt attained a depth of over 3,000 feet without encountering productive oil sands. All the wells are pumped; the gas is saved in a limited number only.

Typical logs.—A typical log near the middle of the productive area is as follows:

Log of well in the southwestern part of the SE. ¼ sec. 20, T. 30 S., R. 22 E.

	Feet.
Brown shale	33
Hard shale	35
Brown shale	105
Oil sand	125
Brown shale	130

	Feet.
Oil sand	153½
Shale	155
Oil sand	164
Shale	167
Oil sand and shale	169
Oil sand	200
Shale	211
Oil sand	231
Hard sand and shale	245
Oil sand	286
Hard sand and shale	297
Oil sand	308
Hard oil sand	320
Hard sand with oil	365
Oil sand	370
Rich shale and oil sand	413
Oil sand and gravel	420
Shale full of oil	460
Rich sand and gas	470
Very hard shale	500
Rich fine sand and gravel	510
Dry sand	516
Shale very rich between streaks	536
Shale	594

A log of a well in this subarea which it is believed penetrates zone B twice is as follows:

Log of well near middle of south line of SE. ¼ sec. 20, T. 30 S., R. 22 E.

	Feet.
Sand	120
Sand	220
Oil sand	283
Rich oil sand	400
Brown shale and shell	770
Asphaltum	782
Brown clay	795
Blue clay	835
Brown shale	840
Asphaltum	880
Dry sand	885
Asphalt	892
Dry sand	895
Asphalt	910
Dry sand	975
Shale	1,020
Dry sand	1,025
Sand and gravel	1,085
Shale, hard	1,087
Shale, heavy oil	1,095
Clay	1,115
Dry sand	1,118
Blue clay	1,165
Shale and shell, clay, no oil	1,475
Water	1,475

BELGIAN—NINETEEN ONE—MONARCH AREA.

Location.—This area embraces the region of sec. 34, T. 30 S., R. 22 E., and includes territory drilled by the Belgian (now Temblor-McKittrick), Nineteen One, and Monarch oil companies.

Structure.—The wells in this area penetrate the basal McKittrick beds on the flanks of the plunging Belgian anticline a short distance southeast of the point where the McKittrick closes around the end of the anticline, covering the Santa Margarita shale, which is exposed along the axis of the anticline from near McKittrick to the southwestern corner of sec. 27, T. 30 S., R. 22 E. The anticline enters sec. 34 near its northwestern corner and, passing southeastward to near the middle of the east half of the section, bends abruptly south and continues its southerly course to the middle of the south line of the SE. ¼ sec. 34, where it again bends to a southeasterly trend and passes off the end of a row of hills under the flats to the southeast, where the structure is hidden. Faults are associated with the anticline especially near the axis on its northeastern flank. The dips on the southeast side are steep, ranging from overturned to normal 70°, while those on the southwest limb vary from 30° to 44°, always normal.

Oil sands.—Oil and heavy tar sands have been encountered in all of the wells so far drilled in this area, the depth below the surface varying from about 450 feet to 1,300 feet, depending on the distance from the anticline. The oil zone consists of alternating blue and brown shale and impregnated sands, the total thickness of the zone as penetrated in the wells ranging from 5 to 50 feet. The sands are coarse and consist largely of quartz grains in which are scattered granitic pebbles.

Product and production.—The product of the wells in this area is black and varies from tar to oil of 14° or 15° Baumé gravity. The wells produce 2 or 3 barrels to 100 barrels per day, those on the northeastern side of the anticline yielding the most and the best oil. The productive wells vary from about 1,000 to 1,100 feet in depth. A little oil and gas were found escaping from between the casing of Monarch No. 1 well in the SW. ¼ sec. 34 when it was visited by the writers in September, 1908, although this well has stood idle for several years. The oils from the Temblor-McKittrick (formerly the Belgian) wells, the only ones operated in this area in September, 1908, pipe their product to a loading rack on the Southern Pacific Railroad at a siding below McKittrick.

U. S.—SEA BREEZE—FEARLESS AREA.

Location.—This area embraces the region of secs. 6, 7, 8, 9, 16, and 17, T. 30 S., R. 22 E., and the eastern part of sec. 1, T. 30 S., R. 21 E. It includes the territory prospected by the McKittrick, U. S., Sea Breeze, Empire, and Fearless oil companies and lies in the foothills immediately north and northwest of McKittrick.

Geology and structure.—The geologic formations exposed in this area are the soft sandstones and clay shales of the McKittrick formation. These beds are affected by two main anticlines, the Gould anticline and a parallel one, which pass from northwest to southeast through the prospected territory. The dips in the strata on the flanks of these anticlines are for the most part over 30° or 40° as exposed at the surface, but near the axes the dips become less and some beds believed to be practically horizontal were noted directly on the axes. In a general way the anticlines are symmetrical, but in certain instances faulting has affected the beds near the axes in such a way as to produce much steeper dips on one flank than on the other. Only five or six prospect holes have so far been drilled in this area, and nearly all of them have obtained oil in commercial quantities.

Oil sands.—The logs of the wells drilled in this area indicate that the oil-bearing zone lies from about 275 to over 500 feet below the surface in the central part. The oil zone is usually between 300 and 400 feet thick, although "stray" or isolated gas and tar sands are often found above and below the major part of the zone. The individual sands vary from 5 to over 40 feet in thickness and four or more of them are usually found within the petroliferous zone. The sands are separated by partings of blue clay, shale, or hard sand shell, which show about the same variation in thickness as is shown by the oil sands. The sand consists of quartz grains, is usually quite coarse, and often carries granitic pebbles up to three-fourths of an inch or possibly more in diameter. It is incoherent and, as shown by the sumps of the old wells, accompanies the oil from the hole. Some fossil clam shells were reported in the oil sand from one of the wells in the northwestern part of the area.

Product and production.—But little information is available concerning the quality of the oil produced by the wells in this area. At the time of the writer's visit to the field in the fall of 1908 heavy oil was found in the sump of several of the wells, which had the appearance of having been abandoned for at least three or four years. The gravity of this sump oil is probably about 10° or 11° Baumé or possibly heavier. When the oil first comes from the well it is said to have a gravity of about 14° Baumé. The production of those wells which were tested was 15 to 25 barrels per day. A considerable amount of sand accompanies the oil.

OIL COMPANIES AND OIL WELLS IN McKITTRICK DISTRICT.

In the following list of companies and wells the locations refer to the Mount Diablo base and meridian. The elevations were taken by aneroid barometer, except those marked "A," furnished by the Associated Oil Company, and those marked "K," by the Kern Trading and Oil Company.

Oil companies and oil wells in the McKittrick district.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Adirondack		1	W. ½ sec. 2, T. 30 S., R. 21 E	1,210
Argonaut. (*See* Everett.)				
Associated	Del Monte	1	NE. ¼ sec. 13, T. 30 S., R. 21 E	
Do	do	2	do	1,232 (A)
Do	do	3	do	1,197 (A)
Do	do	4	do	1,258 (A)
Do	do	5	do	
Do	do	6	do	
Do	do	7	do	1,205 (A)
Do	do	8	do	1,240 (A)
Do	do	9	do	1,251 (A)
Do	do	10	do	1,267 (A)
Do	do	11	do	1,325 (A)
Do	do	12	do	1,202 (A)
Do	do	13	do	
Do	do	14	do	1,272 (A)
Do	do	15	do	1,247 (A)
Do	do	16	do	1,270 (A)
Do	do	17	do	1,263 (A)
Do	do	18	do	1,279 (A)
Do	do	19	do	1,291 (A)
Do	do	20	do	
Do	do	21	do	
Do	do	22	do	
Do	do	23	do	
Do	do	24	do	
Do	do	25	do	
Do	do	26	SE. ¼ sec. 13, T. 30 S., R. 21 E	
Do	do	27	NE. ¼ sec. 13, T. 30 S., R. 21 E	
Do	do	28	do	
Do	do	29	do	
Do	do	30	do	
Do	do	31	do	
Do	do	32	do	
Do	do	33	do	
Do	do	34	do	
Do	do	35	do	
Do	do	36	do	1,174 (A)
Do	do	37	do	1,167 (A)
Do	do	38	SW. ¼ sec. 18, T. 30 S., R. 22 E	
Do	do	39	do	
Do	do	42	NW. ¼ sec. 19, T. 30 S., R. 22 E	
Do	do	49	do	1,295 (A)
Do	do	50	do	
Do	do	52	do	1,302
Do	do	53	do	1,319
Do	do	58	do	
Do	do	59	do	
Do	do	60	do	
Do	do	61	do	1,302 (A)
Do	Giant	1	Sec. 20, T. 30 S., R. 22 E	1,300
Do	do	2	do	1,212
Do	do	3	do	1,385
Do	do	4	Sec. 13, T. 30 S., R. 21 E	1,190 (K)
Do	do	5	Sec. 20, T. 30 S., R. 22 E	1,290
Do	do	6	Sec. 13, T. 30 S., R. 21 E	1,212 (A)
Do	do	7	do	1,212
Do	do	8	do	1,254 (A)
Do	do	9	do	1,210 (A)
Do	do	10	do	1,229 (A)
Do	do	11	do	1,259
Do	do	12		
Do	do	13		
Do	do	14		
Do	do	15		
Do	do	16	Sec. 11, T. 30 S., R. 21 E	1,340 (A)
Do	do	17	do	1,297
Do	do	51	Sec. 19, T. 30 S., R. 22 E	1,414 (A)
Do	do	18	Sec. 11, T. 30 S., R. 21 E	1,293
Do	do	19	do	1,315
Do	do	20	do	1,400
Do	do	21	do	1,420
Do	do	1	NE. ¼ sec. 19, T. 30 S., R. 22 E	1,150
Do	Goodyear	2	SW. ¼ sec. 30, T. 30 S., R. 21 E	1,380
Do	Nineteen hundred and one.	1	SE. ¼ sec. 34, T. 30 S., R. 22 E	1,530
Do		2	do	1,350
Do	Shamrock	1	SE. ¼ sec. 12, T. 30 S., R. 22 E	1,329
Do		2	do	1,370 (A)
Do		3	do	1,377 (A)

Oil companies and oil wells in the McKittrick district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Associated		4	SE. ¼ sec. 12, T. 30 S., R. 22 E.	
Do		5	....do	1,432 (A)
Do	Shamrock	6	....do	1,444 (A)
Do	....do	7	....do	1,376 (A)
Do	....do	8	....do	1,464 (A)
Do	....do	9		
Do	....do	10		
Do	California Standard.	1	SW. ¼ sec. 20, T. 30 S., R. 22 E.	1,271
Do	....do	2	....do	1,276
Do	....do	3	....do	1,275
Do	....do	4	....do	1,270
Do	....do	5	....do	1,275
Do	....do	6	....do	1,268 (K)
Do	....do	7	....do	1,264 (K)
Do	Western petroleum.	1	NW. ¼ sec. 20, T. 30 S., R. 22 E.	1,250
Do	....do	2	....do	1,280
Do	....do	3	....do	1,300
Do	Wier	1	SE. ¼ sec. 3, T. 30 S., R. 21 E.	1,315
Ball & Williams		1	NE. ¼ sec. 2, T. 30 S., R. 21 E.	
Belgian. (*See* Temblor-McKittrick.)				
Belmont. (*See* East Puente.)				
Benedict. (*See* Madison; Merrill.)				
Bowles	Giant	1	NW. ¼ sec. 28, T. 30 S., R. 22 E.	
Do	California Standard.	1	....do	1,268 (K)
Do	....do	2	....do	1,264 (K)
Do	Vancouver	1	....do	[a] 1,250
Do	....do	2	....do	[a] 1,250
Do	Giant	1	NE. ¼ sec. 28, T. 30 S., R. 22 E.	
Do	Spencer	1	SW. ¼ sec. 28, T. 30 S., R. 22 E.	1,200
Do	....do	2	....do	1,190
Bowles & McNear		1	SW. ¼ sec. 2, T. 30 S., R. 21 E.	
Do	Result	1	SE. ¼ sec. 3, T. 30 S., R. 24 E.	1,307
Buena Vista. (*See* K. T. & O.)				
California Standard. (*See* Associated; Bowles.)				
Carmelita. (*See* K. T. & O.)				
Carolina	Everett	1	NE. ¼ sec. 10, T. 30 S., R. 21 E.	1,430
Do		1	....do	
C. J	Keller & Berry	1	NW. ¼ sec. 11, T. 30 S., R. 21 E.	1,340
Do	....do	2	....do	1,365
Do	....do	3	....do	1,415
Do	....do	4	....do	1,440
Do	....do	5	....do	1,415
Do	....do	1	Secs. 11, 12, 13, 14, T. 30 S., R. 21 E.	1,283
Do	....do	2	....do	1,278
Do	....do	3	....do	1,275
Do		4	....do	1,275
Do		5	....do	1,265
Do		6	....do	1,290
Do		7	....do	1,280
Do		8	....do	1,285
Do		9	....do	1,300
Do		10	....do	1,258
Commonwealth		1	SE. ¼ sec. 29, T. 30 S., R. 22 E.	1,300
Cousins. (*See* I. O. P. A.)				
C. W. & B		1	SW. ¼ sec. 18, T. 30 S., R. 22 E.	1,209 (A)
Do		2	....do	1,191 (A)
Do		3	....do	1,193 (A)
Do		4	....do	1,179 (A)
Do		5	....do	1,186 (A)
Dabney. (*See* Providence.)				
East Puente	Belmont	1	SE. ¼ sec. 11, T. 30 S., R. 21 E.	1,437
Do	Jerome	2	....do	1,433 (A)
Do	Belmont	3	....do	1,438
Do	....do	4	....do	1,430
Do		5	....do	
Do		6	....do	
Eclipse, formerly X-Ray. (*See* Jackson No. 1.)				
Empire. (*See* Wible, S. P.)				
Everett	Argonaut	1	SE. ¼ sec. 2, T. 30 S., R. 21 E.	1,300
Do	Graham	1	NE. ¼ sec. 10, T. 30 S., R. 21 E.	1,360
Do	....do	2	NW. ¼ sec. 11, T. 30 S., R. 21 E.	1,250
Do	Venango	1	....do	1,280

[a] Approximate.

Oil companies and oil wells in the McKittrick district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Fearless		1	SW. ¼ sec. 16, T. 30 S., R. 22 E	1,040
Do		2	do	1,070
Giant. (*See* Associated.)				
Goodyear. (*See* Associated.)				
Graham. (*See* Everett.)				
Green		1	SE. ¼ sec. 12, T. 30 S., R. 21 E	1,077 (A)
Independent Oil Producers Agency.	Cousins	1	SW ¼ sec. 18, T. 30 S., R. 22 E	1,207
Do	do	2	do	1,196
Do	do	3	do	1,191
Do	do	4	do	1,185
Do	do	5	do	1,182
Do	do	6	do	1,165
Do	do	7	SE. ¼ sec. 12, T. 30 S., R. 21 E	1,092
Do		1	SW. ¼ sec. 18, T. 30 S., R. 22 E	
Do	Sans Souci	1	SE. ¼ sec. 18, T. 30 S., R. 22 E	1,111
Jackson "No. 1"		1	NE. ¼ sec. 11, T. 30 S., R. 21 E	1,260
Do	Eclipse	1	do	1,400
Do		2	do	1,275
Jackson "No. 2"		2	SW. ¼ sec. 2, T. 30 S., R. 21 E	1,250
Jerome. (*See* East Puente.)				
Jewett	Kern River	1	NE. ¼ sec. 13, T. 30 S., R. 21 E	1,205 (A)
Do	do	2	do	1,195
Do	do	3	do	1,175
Do	do	4	do	1,135
Do	do	5	do	1,225
Do	do	7	do	1,188
Do	do	8	do	1,225 (A)
Do	do	9	do	1,192 (A)
Do	do	10	do	1,202 (A)
Do	do	11	do	1,195 (A)
Do	do	12	do	1,181 (A)
Do	do	13	do	1,216 (A)
Do	do	14	do	
Do	do	15	do	
Kern River		A (6)	NE. ¼ sec. 13, T. 30 S., R. 21 E	1,195
Do		B	do	
Do		C	do	
Do		D	do	
Kimble. (*See* Miller and Lux.)				
Kimble		2	do	1,200
Klondike	Jewel	1	NE. ¼ sec. 2, T. 30 S., R. 21 E	1,315
Do	do	2	do	995
Do	Jap	1	do	1,120
Do	Little Standard	1	SE. ¼ sec. 2, T. 30 S., R. 21 E	1,160
Do	do	2	do	1,340
K. T. & O		1	Sec. 1, T. 30 S., R. 21 E	910
Do		1	SE. ¼ sec. 20, T. 30 S., R. 22 E	1,200
Do		2	do	
Do		3	do	1,233 (A)
Do		4	do	
Do		5	do	1,256 (A)
Do		6	do	1,267 (A)
Do		7	do	1,267 (A)
Do		8	do	1,273 (A)
Do		9	do	1,270 (K)
Do		10	do	1,269 (A)
Do		11	do	1,231 (K)
Do		12	do	1,247 (K)
Do		13	do	1,285 (K)
Do		14		
Do	Carmelita	1	NE. ¼ sec. 33, T. 30 S., R. 22 E	1,400
Do		15	NW. ¼ sec. 13, T. 30 S., R. 21 E	1,217 (A)
Do		16	do	1,224 (K)
Do		17	do	1,242 (K)
Do		18	do	1,267 (K)
Do		19	do	1,287 (A)
Do		20	do	1,226 (A)
Do		21	do	1,243 (A)
Do		22	do	1,252 (A)
Do		23	do	1,273 (A)
Do		24	do	1,302 (K)
Do		25	do	1,305 (K)
Do		26		
Do	Buena Vista	101	SW. ¼ sec. 12, T. 30 S., R. 21 E	1,268
Do		102	do	1,270
Do		103	do	1,248
Do		104	do	1,260
Do		126	do	

Oil companies and oil wells in the McKittrick district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
K. T. & O	Foltz	1	SW. ¼ sec. 11, T. 30 S., R. 21 E.	1,433
Do		2	do	1,438
Little Standard. (*See* K. T. & O.)				
McKittrick-Consolidated		1	N. ½ sec. 18, T. 30 S., R. 22 E.	1,100
Do		2	do	1,100
Madison	Benedict	1	SW. ¼ sec. 11, T. 30 S., R. 21 E.	1,510
Do	do	2	do	1,550
Do		3	do	
McKittrick Extension		1	NE. ¼ sec. 18, T. 30 S., R. 22 E.	
McKittrick Oil Co		1	NE. ¼ sec. 12, T. 30 S., R. 21 E.	1,100
Do		2	NW. ¼ sec. 18, T. 30 S., R. 22 E.	1,115
Do		3	do	1,115
Do		4	Sec. 1, T. 30 S., R. 21 E	910
Do		5	NW. ¼ sec. 18, T. 30 S., R. 22 E.	1,110
Do		6	do	1,115
Do		7	do	1,115
Do		8	NE. ¼ sec. 12, T. 30 S., R. 21 E.	980
Merrill	Benedict	1a	SW. ¼ sec. 11, T. 30 S., R. 21 E.	
Miller and Lux	Kimball	1	SE. ¼ sec. 3, T. 30 S., R. 21 E.	1,220
Do	do	2	do	1,200
Monarch		1	SW. ¼ sec. 34, T. 30 S., R. 22 E.	1,410
Do		2	do	1,400
Nacirema		1	NE. ¼ sec. 6, T. 30 S., R. 22 E.	
Nanticoke		1	SE. ¼ sec. 27, T. 30 S., R. 22 E.	1,200
Nineteen hundred and one. (*See* Associated.)				
Olig Crude		1	SE ¼ sec. 13, T. 30 S., R. 21 E.	1,315 (A)
Do		2	do	1,327 (A)
Do		3	do	
Do		4	do	
Do		5	do	
Do		6	do	1,384
Our Own		1	NE. ¼ sec. 24, T. 30 S., R. 21 E.	1,700
Providence	Dabney	1	NE. ¼ sec. 29, T. 30 S., R. 22 E.	1,237
Do	do	2	do	1,231
Do	do	3	do	1,203 (K)
Do	do	4	do	1,235
Do	do	5	do	1,230
Do	do	6	do	1,244
Do	do	7	do	1,240
Do	do	8	do	1,219 (K)
Do	do	9	do	1,229
Do	do	10	do	1,236
Do	do	11	do	1,257
Do	do	12	do	1,231 (K)
Do	do	13	do	1,268
Do	do	14	do	1,238 (K)
Do	do	15	do	1,238
Do	do	16	do	1,242
Do	do	17	do	1,288
Do	do	18	do	
Do	do	19	do	
Do	do	20	do	
Research		1	NE. ¼ sec. 2, T. 30 S., R. 21 E.	
Result. (*See* Bowles & McNear.)				
Reward		1	NW. ¼ sec. 13, T. 30 S., R. 21 E.	1,220 (K)
Do		2	do	1,242 (K)
Do		3	do	1,236 (A)
Do		4	do	1,215 (K)
Do		5	do	1,250 (K)
Do		6	do	1,275 (K)
Do		7	SE. ¼ sec. 11, T. 30 S., R. 21 E.	1,300
Do		8	do	1,280
Do		9	do	1,287
Do		10	do	1,268
Do		11		1,205 (K)
Do		12	SE. ¼ sec. 11, T. 30 S., R. 21 E.	1,280
Do		13		
Do		14	SE. ¼ sec. 11, T. 30 S., R. 21 E.	1,260
Do		15	do	1,275
Do		16	do	
Do		16	SW. ¼ sec. 12, T. 30 S., R. 21 E.	
Do		18	do	
Do		21	do	
Do		17	NW. ¼ sec. 13, T. 30 S., R. 21 E.	1,275
Do		18		
Do		19	do	
Do		20	do	

Oil companies and oil wells in the McKittrick district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Reward		a	Sec. 11, T. 30 S., R. 21 E	1,300
Do		b	do	1,300
Do		c	do	1,310
San Francisco-McKittrick		1		
Do		2		
Do		3	NE. ¼ sec. 14, T. 30 S., R. 21 E	1,288
Do		4	do	1,287 (A)
Do		5	do	1,276 (A)
Do		6	do	1,279 (A)
Do		7	do	1,285 (A)
Do		8	do	1,286
Do		9	do	1,307
Do		10	do	1,335
Do		11	do	1,370
Do		12	do	
Do		13	do	
Do		14	do	
Do		15	do	
Do		16	do	
Sans Souci. (*See* I. O. P. A.)				
Sea Breeze		1	SW. ¼ sec. 6, T. 30 S., R. 22 E	920
Selkirk		1	SE. ¼ sec. 2, T. 30 S., R. 21 E	1,310
Shale Basin		1	NW. ¼ sec. 29, T. 30 S., R. 22 E	1,195
Do		2	do	
Do		3		
Shamrock. (*See* Associated.)				
Silver Bow		1	NW. ¼ sec. 19, T. 30 S., R. 22 E	1,207 (A)
Do		2	do	1,290
Do		3	do	1,298 (A)
Do		4	do	1,259 (A)
Do		5	do	1,327 (A)
Do		6		
Do		7		
State		1	NW. ¼ sec. 19, T. 30 S., R. 22 E	1,296
Do		2	do	1,299
Do		3	do	1,287
Do		4	do	1,298
Temblor-McKittrick	Belgian	1	NE. ¼ sec. 34, T. 30 S., R. 22 E	1,360
Do	do	2	do	1,415
Do	do	3	do	1,360
Twenty Oil		1	SE. ¼ sec. 20, T. 30 S., R. 22 E	1,195 (K)
Do		2	do	1,201 (K)
U. S. Oil		1	NW. ¼ sec. 6, T. 30 S., R. 22 E	850
Do		2	do	790
Do		3	SE. ¼ sec. 6, T. 30 S., R. 22 E	840
Vancouver. (*See* Bowles.)				
Venango. (*See* Everett.)				
Virginia		1	SW. ¼ sec. 20, T. 30 S., R. 22 E	1,390
Do		2	do	1,410
Do		3	do	1,350
Western Petroleum. (*See* Associated.)				
Wible, S. P	Empire	1	SW. ¼ sec. 8, T. 30 S., R. 22 E	950
Wier. (*See* Associated.)				
X-Ray. (*See* Eclipse.)				

MIDWAY FIELD.

LOCATION.

The region commonly called the "Midway field," and so defined in this report, embraces the belt of territory along the northeastern base of the Temblor Range, beginning in the eastern part of T. 31 S., R. 22 E., and extending in a southeasterly direction as far as the south line of T. 32 S., Rs. 23 and 24 E., which marks the change from the Mount Diablo to the San Bernardino base and meridian. It includes the eastern part of T. 31 S., R. 22 E.; the southeastern portion of T. 31 S., R. 23 E.; practically the whole of T. 32 S., R. 23 E., with the exception of the southwestern corner; and the southwest corner of T. 32 S., R. 24 E.

GEOLOGY.

OUTLINE OF STRATIGRAPHY.

The formations involved in the geology of the developed Midway field include between 3,000 and 5,000 feet of siliceous and clayey shale, containing numerous thin calcareous layers and concretions, of Monterey or lower middle Miocene age; about 1,000 feet of softer, lighter-colored diatomaceous shale, in which are intercalated prominent lenses of coarse granitic sand and conglomerate (the latter containing some bowlders up to 6 feet in diameter) believed to be of Santa Margarita(?) or upper middle Miocene age; a series of at least 1,200 feet of soft sands, clays, and conglomerates believed to be of upper Miocene age, though possibly extending upward into the Pliocene, and assigned to the McKittrick formation; and, finally, stream deposits and alluvium of Recent age. The Santa Margarita(?) and Monterey formations are apparently conformable, while the McKittrick (upper Miocene) overlies these unconformably.

The oil is believed to have originated in the diatomaceous shales of the Monterey and Santa Margarita(?) and to have migrated to either the porous layers included in these formations or to the sands and gravels of the unconformably overlying McKittrick. The productive sands in all the operating wells are included in the base of the McKittrick except, possibly, the deeper sands in some of the wells in the northern part of the field, which may occur in the Santa Margarita (?).

STRUCTURE.

The Midway field is on the monocline on the northeast flank of the Temblor Range. Two subsidiary folds, the Midway and Spellacy Hill anticlines, are developed on the flanks of this monocline. The Midway anticline may be traced on the surface from sec. 36, T. 31 S., R. 22 E., to the western part of sec. 8, T. 32 S., R. 23 E. Evidence offered by the well logs indicates that the anticline continues as far southeast as the northeastern part of sec. 17 in the last-mentioned township, and may possibly here coalesce with the Spellacy Hill anticline. The Spellacy Hill anticline may be traced on the surface, and also in the wells in the developed territory, from the eastern part of sec. 18, T. 32 S., R. 23 E., through the southern part of sec. 17, across the southwestern corner of sec. 16, diagonally through sec. 21, through the southern part of secs. 22 and 23, across secs. 25 and 26, T. 32 S., R. 23 E., and thence with a course slightly south of east out across sec. 31, T. 32 S., R. 24 E., for an indefinite distance toward the Midway Valley. The axes of both anticlines are more or less undulating, and the dips on their flanks vary usually from 5° to 25°, as indicated on the map (Pl. III).

EFFECT OF STRUCTURE ON PRODUCTION.

Incomplete as are the data in hand, they show that the best production and the lightest oil come from the territory adjacent to the nodes of the anticlinal axes, especially near that node which marks the beginning of the plunge of the axis toward the Midway Valley. This fact suggests that the accumulation of oil in this field is possibly controlled, in part at least, by water. The details of structure in the developed territory are shown by contours on Plate III.

OIL SANDS.

General statement.—Less regularity marks the occurrence of the oil sands in the Midway field than in any other in the San Joaquin Valley so far examined by the writers. As a result it has been impossible to make any but tentative correlations for certain parts of the field, and future development may necessitate a revision of portions of the map.

Zone B.—Zone B, the top of which is indicated by contours on Plate III, varies in thickness from 10 to over 800 feet in the wells, the maximum thickness including several intercalated barren sands and shales. Little regularity in the variation is indicated by the logs, although in general the productive beds are apparently more uniform toward the southeast and somewhat thicker toward the middle of the field. The oil sands consist mostly of medium to coarse pebbly quartz sands which sometimes carry cobbles as much as several inches in diameter. Although accompanying the oil in small quantities in most of the wells, the sand is not very troublesome, except in a small area in the southeastern part of the field. This paucity of sand is doubtless due to the lack of gas pressure rather than to the coherency of the containing rock. The most productive sand toward the northwestern part of the area mapped on Plate III is found at depths varying from 250 to over 800 feet below the top of the zone (B) contoured on this map. In the northwestern part of sec. 6, T. 32 S., R. 23 E., the most productive sand is about 265 feet below the top of zone B; in the southern part of sec. 5, T. 32 S., R. 23 E., the most productive sand is 835 feet below the sand mapped as the top of zone B; and in the central part of sec. 31, T. 31 S., R. 23 E., the rich oil sand is about 400 feet lower than the top of zone B.

Zone A.—Throughout the greater part of the field, with the exception of a small area in the southeastern portion, the petroliferous zone (zone A) above zone B contains sands carrying oil in commercial quantities, especially toward its base. In addition to the oil sands, there are tar and gas sands, all separated by more or less important partings of clay and shale. The individual tar and oil sands vary in thickness from 5 to 70 feet, while the main part of the zone seldom extends for more than 200 to 300 feet above the top of zone B. Isolated tar and gas sands are encountered in some of the deeper wells as much as 1,000 feet above zone B. The character of the sands in zone A is similar to that of the sand in zone B, being largely coarse pebbly quartz sands with occasional cobble layers.

Beds above zone A.—For about 400 feet above the top of zone A the shale predominates, while above the shale zone sands and pebble and cobble layers are the more important. Water sands and occasional tar or gas sands are encountered in the shale above the petroliferous zones.

Beds below zone B.—The beds below zone B consist almost entirely of blue and brown shale with occasionally intercalated sand streaks or lenses carrying water or petroleum. Traces of petroleum are said to occur in the shale for a considerable distance below zone B in one of the wells in the northwestern end of the field. Productive sands have recently been encountered in the shales below zone B. Water sand has been found immediately below zone B in some of the wells that have penetrated through this latter zone.

WATER SANDS.

The strata above the petroliferous zones carry less water in this field than in any other so far studied on the flanks of the Temblor Range. The accumulations of water in this part of the formation are usually most pronounced at the base of the sandy zone—that is, about 400 feet above the top of zone A or 600 feet, more or less, above the top of zone B. The wells toward the central part of the area encounter more water as a rule than those farther southeast. The water sands are usually coarse and in many places contain pebbles and cobbles; they vary in thickness from 10 to over 100 feet, as penetrated by the wells.

Water also occurs just above or associated with the upper sands of zone A, intercalated in the shale and clay between zones A and B, and immediately below zone B. These sands in the petroliferous zones are usually coarse and vary from 5 to 20 feet in thickness. Upon the proper understanding and handling of the waters in the sands in the oil-bearing zones depends the future welfare of this field.

Practically all the waters encountered in the field are more or less mineralized, often with salt and sulphur. The capacity of those wells which are utilized for water is said to range as high as 1,200 to 2,500 barrels per day.

PRODUCT.

The oil in the Midway field varies from black to brown in color, and in gravity from about 11° or 12° to as high as 20° or 22° Baumé. The heavier oil as a rule comes from the sands in the basal part of zone A, and in the shallowest wells (those near the axis) from the sands in zone B. The lighter oil comes from zone B, usually from the wells that are deeper, but still not far from the axes of the anticlines. Gas accompanies the oil in all the wells, but except in a few near the axis in the southeastern portion of the field it is not under the strong pressure that affects it in the Sunset field. As a result of this low gas pressure little sand accompanies the oil except in rare instances.

PRODUCTION.

Lack of means of transport until quite recently has precluded the proper testing of the wells, so that little can be said as to their ability to produce under continued operation. Initial productions at the rate of 2,500 barrels or more per day have been reported for two or three wells in the field, but the individual average for the whole territory is believed to be less than 100 barrels per day. The production is greatest in the southeastern part of the field, where it is not uncommon for wells to make from 150 to 250 barrels per day; toward the west-central part of the field the wells so far tested will not average more than 50 to 100 barrels. The low production as compared with other fields is believed to be due largely to lack of gas pressure, rather than to thinness of sands. Such a theory leads to the conclusion that the wells will be long-lived, with a fairly uniform rate of production.

METHODS.

The productive wells vary in depth from 500 to over 2,800 feet, and practically all secure their oil by pumping. The method of handling the water is interesting, and is described in more or less detail under each area. The conditions are so varied that each well usually has to be handled somewhat differently from the others, even from its nearest neighbor.

LOCAL AREAS OF MIDWAY FIELD.

UNION—BROOKSHIRE—HAWAIIAN AREA.

Location.—The area denoted by the heading embraces the eastern half of the northern part and the eastern one-third of the southern part of T. 31 S., R 23 E. It includes wells now drilled or being drilled by the Union, Bear Creek, Majestic, Brookshire, Pioneer Midway, California Midway, Chanslor-Canfield Midway (Santa Fe Railway), Hawaiian, Mays, and several other oil companies.

Underground geology and production.—Development in this area has all taken place since the preparation of the main part of this bulletin, and all of the following notes concerning the area have been added as the report is going to press. The wells vary in depth from about 1,000 to over 2,800 feet and penetrate from 25 to 200 feet of productive sand. The sand is usually coarse and consists largely of water-worn granitic material. Tar sands are encountered in the wells intermittently from about 800 feet below the surface downward to the productive zone. In some of the deeper wells the uppermost tar sands are as much as 1,500 feet above the top of the productive zone. Water sands usually occur between the uppermost tar sands and the productive measures. The oil varies in gravity from 13° Baumé in the northern part of the area to 19° in the southern part. Oil claimed to be of 20° to 25° Baumé gravity is found in the shale above the most productive sands. Only two or three wells in the area have been properly tested and one of these is now flowing more than 2,000 barrels per day. Extravagant claims of extraordinary production based upon temporary initial flows have been made for several of the wells but until these wells are actually tested nothing definite regarding them can be known.

OREGON MIDWAY—SANTA FE—LOCKWOOD AREA.

Location.—The area denoted by the heading embraces the northwestern part of the developed Midway field, and consists of the southern edge of sec. 31, T. 31 S., R. 23 E., and secs. 5, 6, 7, 8, 9, 15, 16, and 17, T. 32 S., R. 23 E. It includes the wells operated by the Midway Crude, Midway of Oregon, Santa Fe Railway, and Lockwood oil companies, and occupies the flanks of the Temblor monocline and of the subsidiary Midway anticline where it merges into the monocline.

Zone B.—There is less regularity in the sands comprising zone B and also in the other strata of this area than in the beds of any other field so far studied in detail on the flanks of the Temblor Range. As a result it has been impossible to locate the top of zone B with certainty in many of the wells of the area. Tracing the oil sands from the region of sec. 22, T. 32 S., R. 23 E., where zone B is easily recognized, it has been possible to locate what is believed to be the equivalent of this zone in most of the wells, and as the horizon at which this occurs is checked by the other criteria used in correlation, this horizon has been mapped by contours on Plate III.

Zone B, as penetrated by the wells, varies in thickness from 10 or 15 feet to about 800 feet, this latter figure doubtless including intercalated barren strata or partings, of which several are usually indicated in the logs showing the details of the zone. No regularity has been recognized in the variation in thickness of the zone, logs showing maximum and minimum figures being found in various parts of the area. This variation is doubtless due in part to the personal factor introduced by the drillers.

The sands of zone B consist mostly of coarse quartz grains and generally carry pebbles and in many places cobbles of considerable size. Although the sand is more or less incoherent, very little accompanies the oil, owing to the low gas pressure in this part of the field.

The partings in the zone and the beds immediately above and below it are of blue clay or shale or hard sand shell. Water is found below it in most of those wells that penetrate many feet below its base.

Zone A.—As is the case in the area next southeast, zone A consists of a number of sands carrying oil, often in commercial quantities. Zone A proper usually includes strata for 200 or 300 feet above the top of zone B, although beds showing traces of oil and gas are encountered as high as 600 feet above the latter. The sands in zone A are similar in composition and grain to those of zone B and are separated by partings of shale and shell. Zone A is separated from zone B by 30 to nearly 200 feet of blue or brown shale, this shale stratum being fairly regular in thickness and persistent throughout the southeastern portion of the area. So far as known, no well now in operation derives its supply solely from zone A, so that statements concerning the properties of its oil are meager. The oil is known to be heavier than that found in zone B, and little gas accompanies it. Water sands occasionally occur intercalated in zone A, and also commonly in the strata between it and zone B, the latter case being especially noticeable in some of the wells in the northwestern portion of the area.

Beds above zone A.—The beds for about 400 feet above the top of zone A consist of blue shale, with minor quantities of sand often carrying traces of oil and gas. Above the shale zone the strata are largely coarse or pebbly sands and sometimes cobble-bearing layers. Water is sometimes encountered in sands in the beds above zone A.

Beds below zone B.—The beds below zone B consist largely of blue and brown shale and sandy shale usually showing traces of oil. Any coarse sands immediately below zone B are liable to carry water.

Water sands.—Most of the underground water in this area occurs either associated with or below the petroliferous zone. Surface waters are encountered in some of the wells in coarse sands varying in thickness from 10 to over 100 feet, usually at the bottom of the sandy zone about 400 feet above the top of zone A. Water also occurs associated with the tar and oil sands of zone A, and also in the beds between zones A and B in layers of coarse sand from 10 to 20 feet thick, especially in the northwestern portion of the area. Where water occurs in zone A, the thickness of the nonpetroliferous strata between zones A and B is usually much greater than where no water occurs in zone A. This is doubtless due to the water driving the hydrocarbons out of the strata in which it collects.

The water from the well in the northeast corner of sec. 7, T. 32 S., R. 23 E., is believed to come from a sand in the top of zone A. The abundance of water at this particular locality, amounting to 2,500 barrels per day, is peculiar, as no such amounts are found in adjacent wells, although what is believed to be the same horizon is encountered in them. The water from this well is fairly good and is used for domestic and other purposes throughout the Midway district.

Water is known to occur in sands immediately below the base of zone B in some of the wells, and is believed to be present at the same horizon throughout a large part of the area, although care in drilling has avoided penetrating it in most of the wells so far put down.

It is reasonable to suppose that as development progresses toward the northeast and down the dip of the strata, water will be found more and more abundant in the petroliferous as well as the other zones, but it is the belief of the writers that the increase in the water will tend to concentrate the petroleum into narrow isolated beds without materially decreasing its amount.

Product.—The wells in this area yield black to brown oil varying in gravity from 12° to 20° Baumé. The heaviest oil comes from the southeastern part, the lightest from the deeper wells in sec. 8, while oil of about 16° to 17° Baumé comes from the northern part and many of the wells in the central part. The oil in zone B is known to be lighter than that in zone A. Little sand and usually not much gas accompanies the oil.

Production.—Little definite information is at hand relative to the productiveness of the wells in this part of the field. Initial flows of as much as 2,500 barrels per day are known to have occurred. Those wells that have been pumped for a considerable time yield little over 100 barrels each per day.

Methods.—The wells in this area vary in depth from about 900 to over 2,300 feet and all obtain their oil by pumping. The manipulation of the casing differs from well to well, but in general it may be said that the first string is landed between zone A and zone B in the shallower wells, and at or near the top of zone A in those a little deeper.

Typical logs.—A typical log for the northern part of the area is as follows:

Log of well in the NW. ¼ sec. 8, T. 32 S., R. 23 E.

	Feet.
Yellow sandy clay	290
Coarse gravel	310
Reddish sand	375
Sandstone	385
White sand	400
Light-brown clay	405
Dark oily brown clay	410
First oil sand	430
Dark-blue shale	730
Light-blue sandy shale	820
Hard shell	823
Oil sand (top of zone A, proper)	835
Sandy blue shale	840
Water sand	845

	Feet.
Blue clay (water off 11⅝ inches at 852)	853
Hard shale, gray stone	858
Blue shale and blue clay streaks	865
Some sandy, small shale pebbles	865
Water sand and water	870
Brown shale	875
Oil sand	880
Blue shale and fine gravel	895
Hard gray shell	898
Oil sand and oil (good)	905
Sandy blue shale and fine sand	915
Hard shell	920
Coarse water sand	950
Sandy blue shale	960
Fine blue shale	964
Blue clay	980
Blue shale (sandy shell at 985)	985
Water sand	990
Blue shale	1,000
Fine blue clay (landed 9⅝ inches at 1,007 and water off)	1,025
Sticky blue shale	1,035
Blue shale and shell	1,050
Blue shale	1,070
Blue clay	1,085
Blue shale	1,095
Brown shale	1,110
Oil sand (producing), top of zone B	1,134
Shale and blue clay	1,137
Oil sand (producing)	1,149

A characteristic log in the south-central part of the area is as follows:

Log of well in the NE. ¼ sec. 17, T. 32 S., R. 23 E.

	Feet.
Clay and surface formation	174
Clay	186
Pink sand	235
White sand	275
Oil sand	287
Blue clay	332
Shale	426
Dry oil sand	432
Shell and shale	680
Oil sand (top of zone A)	701
Shell and shale with oil	747
Oil sand and cobbles	788
Shell and shale with oil	815
Oil sand	826
Shale with oil	857
Oil sand	870
Blue clay	890
Oil sand (top of zone B)	895
Shale with oil	905
Oil sand	908

	Feet.
Shale	918
Oil sand	925
Shale	935
Oil sand	960
Shale	1,065

A typical log in the southern part of the area is as follows:

Log of well in SW. ¼ sec. 16, T. 32 S., R. 23 E.

	Feet.
Surface	150
Clay and sand	385
Water sand	393
Blue clay	400
Water sand	410
Blue clay with streaky sand	840
Clay, showing of oil	970
Sand	995
Clay	1,045
Oil sand	1,225

FAIRBANKS—BURKS—MOUNTAIN GIRL AREA.

Location.—This area comprises the southeastern part of sec. 16, the whole of secs. 14, 15, 21, and 22, and all of sec. 23 except the southeastern corner, in T. 32 S., R. 23 E. It includes wells operated by the following companies: Santa Fe Railway (secs. 15 and 21), Fairbanks, Burks, Arminta, Bay City, Gypsy, Mountain Girl, Producers Guaranteed, Knob Hill, and Babcock (formerly Josephine). The area lies on the flanks of the Spellacy Hill anticline, mostly on the southeast side of the axis.

Zone B.—Two fairly well-defined productive oil zones are encountered in most of the wells in this area, the lower one, zone B, being the most productive. Zone B varies in thickness in the wells from 15 to over 100 feet, the latter figure doubtless including intercalated barren sands and shale, of which there are usually one or more throughout the zone; the best producers usually tap from 15 to 50 feet of sand. The zone differs greatly from well to well and little correspondence in the logs can be noted except in a most general way. The sands of zone B usually consist of medium to coarse-grained quartz sand which, in some places in the central part of the area, carries pebbles and cobbles of granite or other similar crystalline rocks. The sand is incoherent, and more or less of it accompanies the oil in most of the wells.

Zone A.—The zone above zone B that in other areas is usually characterized by tar and gas sands contains layers carrying oil in commercial quantities in some of the wells in the territory under discussion. It is true the oil is rather heavy, usually ranging from 11° to 13.5° Baumé, and the production is never over 30 to 50 barrels per day, but the product is worth saving, and for this reason the water should be so handled in the wells as to protect these upper sands. Zone A comprises about 200 to 300 feet of strata above the top of zone B, and usually consists of several well-defined oil sands, each varying from 5 to 60 feet in thickness and separated by partings of blue or brown shale. The lowest sand in zone A is usually separated from the top of zone B by 50 to more than 200 feet of blue clay. In the northwestern part of the area water sand occurs in this blue clay. The sands of zone A are similar to those of zone B, consisting largely of quartz sand sometimes carrying pebbles and cobbles. Judging by some of the logs of wells in the northwestern part of the area, the line of separation of zones A and B is not as well defined in this region as in the territory farther southeast.

Beds above zone A.—The beds immediately above zone A consist largely of blue shale with minor amounts of sand, in one or more layers of which water and sometimes a little tar is encountered; from about 400 feet above the top of zone A upward the formation is mostly sand with less important shale layers.

Beds below zone B.—No log of a well in this area which passed far below zone B was available to the writers in their study, so that definite statements are impossible. The surface conditions, however, indicate that the beds below the productive zone consist largely of blue and brown shale, in which it would not be surprising to find isolated oil or water sands. Water sands immediately underlie zone B in most of the wells that penetrate through the productive zone.

Water sands.—Water is very troublesome in many of the wells in this area, and unless its occurrence is carefully studied and the wells are properly handled, it will ruin much of the territory that otherwise ought to be productive. Water occurs in sands just above or associated with the upper layers of zone A in some of the wells, especially in the southeastern part. Water occurs also just below zone B both in the southeastern and central portions, and in sands between zones A and B in the northeastern end. The distribution of the water sands is irregular and the behavior of the water different in each of the wells. The water sands above zone A vary in thickness from 15 to 50 feet and yield highly mineralized water, often with salt and sulphur; the sand between zones A and B lies 10 feet or more below the lowest bed in zone A and is 4 or more feet in thickness; the water sand below zone B is separated from it by 5 to 30 feet of clay or shale, is 30 feet more or less in thickness, and yields salt water, as much as 700 or 800 barrels per day, it is said, coming from it in one well in the northern part of sec. 26.

Product.—The product of zone B is a black oil varying in gravity from about 13.5° Baumé in the shallower wells at the northwestern end of the area to 17° or 19.5° in the deeper wells in the southeastern end. Some sand accompanies the oil in a few of the wells, especially toward the southeast end of the area, but as a rule little difficulty is experienced as compared with that in the next area southeast. The oil from the sands of zone A is black and heavier than that from zone B, varying in gravity from 12.8° to 15° Baumé. Gas in moderate quantities occurs with the oil and also in isolated sand lenses throughout zone A.

Production.—The production of the wells tapping zone B varies from 50 to over 250 barrels per day per well; that of wells deriving their supply from zone A varies from 10 to possibly 50 barrels per day. One well near the middle of the line separating secs. 23 and 26, passing through zone B into the water sand, is said to have yielded 700 or 800 barrels of water and 20 barrels of 14° Baumé oil per day. As zone B yields oil of 15° to 19° Baumé in other wells in the same locality, the low grade yielded by the water-contaminated well is accounted for by the deleterious effect of the water on the oil.

Methods.—The productive wells in this area vary from 500 to about 1,600 feet in depth; some untested wells are much deeper than this, but so far no authentic data concerning them have been obtained. The question of the water associated with the oil zones is a serious one for this area. Great care should be used in shutting off the water lying above or associated with the upper beds of zone A, else this water may follow down the casing and penetrate the sands of zone A, which, though they may not be utilized in the particular well yielding the water, should be preserved for adjacent wells in which the oil of zone A may be of commercial importance. Furthermore, wells which shut off the water above zone A, but pass through this zone without utilizing any of its sand and then go into the water sand between zones A and B, should isolate the sands of zone A, either by landing a string of casing between them and the water sand below or else by thoroughly cementing off the water in the lower sand. The suggestions above mentioned are for the protection of the productive sands of zone A; similar precautions should be taken in reference to zone B by shutting off the water where it occurs above and below it (if tapped).

Typical logs.—A log typical of the northwestern end of the area is as follows:

Log of well in NW. ¼ sec. 22, T. 32 S., R. 23 E.

	Feet.
Yellow surface formation, largely sand	300
Blue clay and shale	530
Oil sand, traces of 15° Baumé oil and some gas	540
Blue clay, shale, and sand	700
Oil sand, traces of oil or tar	705
Blue clay and shale, minor amounts of sand	1,365
First oil sand, 30 to 50 barrels per day of 12.8° oil (zone A)	1,406
Yellow and brown clay	1,416

	Feet.
Water sand, with water rising to 1,300 feet	1,420
Blue clay	1,520
Second oil and sand (zone B)	1,535+

A characteristic log of the central part of the area is as follows:

Log of well near middle line between secs. 22 and 23, T. 32 S., R. 23 E.

	Feet.
Sand and gravel	200
Yellow clay	240
Clay and water	245
Hard sand and clay	300
Blue shale	316
Yellow sand	376
Soft sand (gray)	391
Blue shale (sandy)	426
Yellow sand	451
Gray sand	481
Blue shale	514
Tar sand	519
Blue shale (sandy)	599
Blue shale	625
Hard shell	628
Blue shale (with hard shells)	750
Blue clay	825
Hard shell	830
Blue shale	968
Tar sand	973
Blue shale	1,088
Brown shale	1,093
Hard shell	1,098
Oil sand	1,113
Brown shale	1,123
Oil sand	1,168
Blue shale	1,173
Oil sand	1,233
Blue shale	1,308
Brown shale	1,383
Oil sand (rich)	1,398
Hard shell	1,401
Black shale	1,433
Hard shell, water below lots of it, and salt, in a coarse water sand	1,465

A typical log of the area near the axis of the Spellacy Hill anticline is as follows:

Log of well in central part of the S. ½ sec. 22, T. 32 S., R. 23 E.

	Feet.
Bed gravel	50
Blue clay	400
Gray sand	415
First indication of oil	425
First oil sand	430
Blue clay	440
Second oil sand	490

	Feet.
Third oil sand	540
Shale and blue clay	590
Dry oil sand	600
Sand and gas	615
Brown shale over sticky sand, thin layer of sand, with gas at 660; more gas at 700.	1,100
Oil sand	1,105
Brown shale	1,400

BABCOCK—MASCOT—TWENTY-FIVE AREA.

Location.—This area comprises the southern part of secs. 23 and 24, the whole of secs. 25 and 26, T. 32 S., R. 23 E., sec. 30, T. 32 S., R. 24 E., and the territory adjacent to these. It includes, among others, properties operated by the following companies: Babcock (formerly Josephine), Talara, Santa Fe Railway (sec. 24), Mascot, Opal, Safe, Altoona, Crœsus, Twenty-five, Paraffine, and Standard. The area is almost entirely on the northeastern flank of the Spellacy Hill anticline, adjacent to where it bends from a southeasterly to an easterly trend and fades off into the Midway Valley.

Zone B.—The more productive strata of the area occupy a zone (zone B) varying in thickness, as penetrated in the wells, from 11 to about 150 feet, the greater thickness usually including more or less intercalated shale and barren sand. In some of the wells, however, a thickness of over 100 feet of continuous productive sand is reported. The sand is generally medium to coarse grained, and consists of grains of quartz with minor amounts of other minerals. Cobbles and pebbles occur in the oil zone in the wells, especially in the northwestern part of the area. Near the southeastern edge of the area the productive measures consist of two or three sands, the lowest being the richest and carrying the lightest oil.

Zone A.—Beds or lenses more or less impregnated with oil or tar, and usually containing gas, are intercalated in the shale and sand strata above the top of the productive zone. In some of the deeper wells these tar sands occur 1,000 feet or more above zone B, while in the shallower ones zone A is seldom over 500 feet in thickness in the wells, and often consists of but one or two impregnated sands. The individual tar sands are 5 to 70 feet thick, and little uniformity is to be noted in the sands of adjacent wells, owing to the local lenslike occurrence of the strata, and in part also, no doubt, to the personal factor brought in by the drillers reporting the logs. The most persistent tar sands overlie zone B, usually separated from it by shell or shale varying from a mere parting to 40 feet or more in thickness. Many of these sands in the base of zone A contain more or less oil, some even enough for commercial exploitation. The sands vary from medium to coarse grained quartz, and sometimes carry pebbles and cobbles. Water is not reported as associated with any of the tar sands in zone A, although in one instance an isolated tar sand occurs above a water sand. Water usually marks the top of the zone.

Beds above zone A.—The beds above zone A consist of alternating shale and sand layers, with occasional strata of pebbles and cobbles. The sand beds seem to predominate, more especially in the upper part of the series.

Beds below zone B.—Only a few wells in the productive area have completely penetrated zone B, and these, with one exception, have stopped in the water sand that lies below zone B. A well on the southwestern flank of the Spellacy Hill anticline, after being drilled through zone B, encountered brown shale with occasional sands, one of which contained a trace of oil.

Water sands.—Very little water is encountered in the strata above zone A, the comment in one log being that, although water was present, there was not enough to drill with. The water zone lies from a few feet above the top of zone A to near the surface; the sands are 5 to 50 feet thick, and in composition vary from coarse to pebbly quartz sand. The water is always highly mineralized.

Water occurs below zone B in several wells, and is believed to occupy a similar position below those which do not completely penetrate the productive sand. One well near the northwestern end of the area is said to be capable of yielding 700 to 800 barrels of good boiler water a day, the source of the water being uncertain, although it is believed by the operator that the water comes from below or possibly between the sands of zone B, as oil in small quantities accompanies the water.

Product.—The yield in the vicinity of Spellacy Hill varies from black oil of 14° Baumé gravity to brown oil of 20° to 22° Baumé. In general the heavier oil of 14° to 16° Baumé gravity occurs in the wells nearest the axis of the anticline, while the lighter oil comes from the deeper wells some distance away from it. The western part of the NW. ¼ sec. 25 includes an area in which the oil is particularly light, ranging from 17° Baumé in some of the Twenty-five wells to 22° in the Altoona well. It is the belief of the writers that this lighter oil occupies a particular lens of sand which extends throughout a more or less limited area, and that even within this particular lens the oil varies from place to place. Sand accompanies the oil in considerable quantities in the area near the anticline, especially in the northwestern portion. Gas pressure is also strong in the same general area and occasionally in the deeper wells.

Production.—The production of the individual wells varies from 8 or 10 barrels per day in the wells on the southwest side of the anticline to 300 barrels in the best producers. One of the best wells in the northern part of the area is said to have started with a production of over 500 barrels per day; at the end of a year it was giving about

250. The average for the better wells in sec. 25 is between 150 and 250 barrels per day. Only two or three of the more gassy wells flow, the others being pumped.

Methods.—The productive wells in this area vary from about 800 to 1,800 feet in depth. Water is usually shut off in the blue clay just above zone A. Where the wells have inadvertently penetrated the water sand under zone B, the well is usually plugged up to the base of the productive sand and then perforated from that point upward. It has been found best to pump certain of the wells in which the sand is bothersome only two or three hours each day.

Typical logs.—A typical log of one of the wells not far from the axis of the anticline in the southeastern part of the area is as follows:

Log of well in middle of the W. ½ sec. 25, T. 32 S., R. 23 E.

	Feet.
Brown sand	250
Blue clay	425
Clay	500
Gray sand, dry	597
Hard sand, shell, some gas, heavy asphalt oil	600
Muddy sand, light blue	622
Blue shale	624
Dry oil sand	628
Sheets of mud shale and asphalt sand	725
Blue clay	732
Clay, hard shell	735
Asphalt sand	738
Thin strata of dry oil sand and shale	755
Hard brown sand, stained with oil	773
Shale and loose dry oil sand	785
Sheet of shale and hard gray sand	835
Blue shale	855
Light-colored gray shale	865
Hard gray sand	895
Blue clay	910
Oil sand, show of oil	915
Strata of shale and gray sand	965
Muddy sand, showing brown oil	1,080
Thin blue clay	1,095
Soft muddy sand	1,105
Gray shale	1,110
Oil sand	1,113
Gray shale	1,117
Oil sand	1,120
Gray shale, strata of dry sand and gas	1,151
Hard gray sand and shell	1,154
Close hard gray shale	1,160
Some gas, close solid oil sand, good show of oil	1,168
Light traces of shale in close oil sand	1,190
Hard sand shell; big gas strata; blew water out of hole over derrick roof	1,194
Very rich soft oil sand	1,202
Close bed of oil sand	1,212

	Feet.
Very rich soft oil sand	1,222
Very hard shell	1,224
Rich soft oil sand; bottom of this streak looks a little heavier	1,257
Soft and hard streak; rich oil sand, light gravity	1,326
Hard sand shell	1,335
Brown shale.	

A log of one of the deeper wells along the northeastern edge of the tested territory is as follows:

Log of well in southern part of sec. 24, T. 32 S., R. 23 E.

	Feet.
Sand	130
Clay	200
Conglomerate	295
Blue clay	330
Sand	445
Shale	454
Blue clay	615
Hard sandy shell	628
Clay	638
Hard shale	648
Clay	662
Hard shale	713
Clay	721
Hard shale	810
Clay	818
Hard shale, clay and shell	1,200
Oil sand (not much oil)	1,215
Shale	1,234
Sand	1,265
Clay	1,270
Hard shell	1,298
Sand (more water)	1,310
Clay and few shells	1,491
Shale and clay	1,557
Oil sand, shows much oil and gas	1,567

ARCATA—MONTE CRISTO—SUNSET MONARCH AREA.

Location.—The area denoted by the heading, the southernmost in the Midway field, comprises secs. 31 and 32, T. 32 S., R. 24 E., the eastern part of the fractional sec. 27, the whole of fractional sec. 26, T. 12 N., R. 24 W., and the territory immediately adjacent to these. It includes among others the wells of the Arcata, Monte Cristo, Fort Wayne, Union, Stratton, Nanticoke (now Union), and Sunset Monarch oil companies. It lies in the region where the Spellacy Hill anticline merges into the flank of the Thirty-five and California Fortune anticlines.

Zone B.—Insufficient data are at hand to warrant many definite statements concerning the underground geology in this area. Zone

B lies about 1,200 to over 1,600 feet below the surface in the wells the logs of which were examined. It consists of the usual coarse quartz sands carrying pebbles. The productive zone consists of three separate thin sands within a thickness of about 100 feet, or, elsewhere, one or two somewhat thicker sands within about 60 feet. Tar and poorly productive sands in some places form a zone 100 to 300 feet thick immediately overlying the productive sands (zone B). These tar sands are interbedded with barren shales and rarely with water sands.

Zone A.—A zone of tar sands from 10 to about 100 feet thick lies 300 to 400 feet above the top of zone B. The individual sands, of which there are one to three in the different wells, are 10 to 30 feet thick in the wells, and consist of coarse quartz sands.

Beds above zone A.—The beds above zone A consist of sand and blue shale with occasional gravel layers, especially near the surface.

Beds below zone B.—The only well which has apparently penetrated entirely through zone B encounters blue shale with intercalated hard shells and occasional traces of oil for at least 200 feet below the base of zone B.

Water sands.—Two to seven water sands occur above the top of zone A, and in one well a water sand 10 feet in thickness occurs between the top of the horizon of the tar sands and the top of the tar sand immediately overlying the productive zone B. In another well water is reported between two tar sands about 100 feet above zone B. These sands are coarse but yield little water.

Product and production.—The product of the wells in this area is most variable, one well yielding heavy oil of 11½° or 12° Baumé gravity, while another is said to yield oil considerably lighter. The individual wells produce from 30 to 50 barrels per day, although it must be admitted that none of the few put down have yet been thoroughly tested.

BUENA VISTA HILLS AREA.

Location.—The Buena Vista Hills area embraces the Buena Vista Hills, which lie largely in the southeastern part of T. 31 S., R. 23 E., and the northern part of T. 32 S., R. 24 E. Among the companies operating in this area are the Standard and the Honolulu.

Wells.—Only two wells have been drilled in this area. One drilled by the Honolulu Oil Company in the SE. ¼ sec. 10, T. 32 S., R. 24 E., encountered a terrific gas pressure in sand at a depth of a little over 1,600 feet and a 200 to 500 barrel flow of oil at about 2,600 feet. The Standard Oil Company drilled a well in the SW. ¼ sec. 26, T. 31 S., R. 23 E., which also encountered a strong gas flow at 1,725 feet. This gas has been confined and is now being used by the company for development purposes in other parts of the Midway district.

OIL COMPANIES AND OIL WELLS IN MIDWAY DISTRICT.

In the following list of wells and companies the locations refer to the Mount Diablo base and meridian. The elevations, which are approximate, are from the Atchison, Topeka and Santa Fe Railway, or taken by aneroid barometer.

Oil companies and oil wells in the Midway district.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Alpine	Bay City	1	NW. ¼ sec. 22, T. 32 S., R. 23 E	1,270
Do		2	do	
Do		3	do	
Altoona (W. T. & M.)		1	NW. ¼ sec. 25, T. 32 S., R. 23 E	1,465
Do		2	do	
Alvarado		1	NW. ¼ sec. 15, T. 32 S., R. 23 E	1,260
Do		2	do	
Amazon	Producers Guaranteed.	1	SW. ¼ sec. 22, T. 32 S., R. 23 E	1,350
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Andrews. (*See* Oskaloosa.)				
Arcata. (*See* Santa Fe.)				
Arminta		1	NW. ¼ sec. 22, T. 32 S., R. 23 E	1,265
Do		2	do	
Babcock Petroleum	Josephine	1	SE. ¼ sec. 23, T. 32 S., R. 23 E	1,260
Do	do	2	do	1,390
Do	do	3	do	1,375
Do		4	do	
Do		5	do	
Do		6	do	
Do		7	do	
Do		8	do	
Bay City. (*See* Alpine.)				
Bear Creek		1	Sec. 14, T. 31 S., R. 22 E	1,330
Do		2	do	
Do		3	do	
Do		4	do	
Bedrock	Equitable Petr	1	SW. ¼ sec. 14, T. 32 S., R. 23 E	
B. H. & C	Hall & Barlow	1	NW. ¼ sec. 25, T. 32 S., R. 23 E	
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Do	do	5	do	
Brocton		1	SW. ¼ sec. 23, T. 32 S., R. 23 E	
Brookshire		1	Sec. 24, T. 31 S., R. 22 E	1,234
Do		2	do	
Do		3	do	1,236
Do		4	do	
Burkes		1	NE. ¼ sec. 22, T. 32 S., R. 23 E	1,285
Do		2	do	1,340
Do		3	do	
Do		4	do	
California-Midway		1	NE. ¼ sec. 32, T. 31 S., R. 23 E	1,190±
Do		2	do	
Carbo-Petroleum		1	NW. ¼ sec. 26, T. 32 S., R. 23 E	
Do		2	do	
Casa. (*See* Jade.)				
Croesus		1	SW. ¼ sec. 25, T. 32 S., R. 23 E	1,635
Do		2	do	1,630
Do		3	do	1,610
Do		4	do	1,655
Do		5	do	1,645
Do		6	do	
Dayton		1	NW. ¼ sec. 9, T. 32 S., R. 23 E	1,280
Dixon. (*See* Knob Hill.)				
Drake & Yancy		1	S. ½ sec. 15, T. 31 S., R. 22 E	
Do		2	do	
Elkhorn		1	SE. ¼ sec. 25, T. 32 S., R. 23 E	1,260
Do		2	do	
Equitable Petroleum		1	NW. ¼ sec. 15, T. 32 S., R. 23 E	
Equitable Petroleum. (*See* Bedrock.)				
Fairbanks		1	NW. ¼ sec. 22, T. 32 S., R. 23 E	1,370
Do		2	do	
Do		3	do	
Fort Wayne. (*See* G. M. B.)				
France		1	NE. ¼ sec. 4, T. 32 S., R. 23 E	

Oil companies and oil wells in the Midway district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
G. M. B	Fort Wayne	1	SE. ¼ sec. 31, T. 32 S., R. 24 E	922
Do	do	2	do	980
Do	do	3	do	
Graham, F. M		1	SE. ¼ sec. 25, T. 32 S., R. 23 E	
Graham & Hall		1	NW. ¼ sec. 26, T. 31 S., R. 22 E	
Greenlee Consolidated		1	NE. ¼ sec. 15, T. 32 S., R. 23 E	
Griffith Crude	Producers Guaranteed.	1	NW. ¼ sec. 23, T. 32 S., R. 23 E	
Gypsy		1	SE. ¼ sec. 22, T. 32 S., R. 23 E	
Do		2	do	
Do		3	do	
Do		1	NW. ¼ sec. 23, T. 32 S., R. 23 E	1,450
Do		2	do	1,290
Do		3	do	
Jolly Joker. (*See* Gypsy.)				
Hartford	Lockwood	1	E. ½ sec. 16, T. 32 S., R. 23 E	
Do	do	2	do	1,500±
Hawaiian (Crandall-Matson)		1	N. ½ sec. 31, T. 31 S., R. 23 E	1,328
Do		2	do	1,254
Do		3	do	1,242
Do		4	do	
Do		5	do	
Honolulu		1	S. ½ sec. 4, T. 32 S., R. 24 E	
Do		1	SE. ¼ sec. 10, T. 32 S., R. 24 E	
Do		1	Sec. 14, T. 32 S., R. 24 E	
Do		2	do	
Do		3	do	
Jade	Casa	1	SW. ¼ sec. 15, T. 32 S., R. 23 E	1,255 (?)
Do	do	2	do	
Do		1	NE. ¼ sec. 15, T. 32 S., R. 23 E	
Knob Hill	Dixon	1	NE. ¼ sec. 23, T. 32 S., R. 23 E	1,210
Do		2	do	
Do		3	do	
Do		4	do	
La Belle		1	SW. ¼ sec. 4, T. 32 S., R. 23 E	
Do		2	do	
Lockwood		1	SW. ¼ sec. 16, T. 32 S., R. 23 E	1,515
Do		2	do	1,460
Do		3	do	1,420
Do		4	do	1,440
Logan-Twitchel		1	SE. ¼ sec. 23, T. 31 S., R. 22 E	
Do		2	do	
Majestic		1	W. ½ sec. 23, T. 31 S., R. 22 E	
Do		2	do	
Manhattan-Midway	Stratton	1	SW. ¼ sec. 32, T. 32 S., R. 24 E	840
Do	do	2	do	930
Marion	Stroud et al	1	SE. ¼ sec. 15, T. 32 S., R. 23 E	
Mascot		1	NE. ¼ sec. 26, T. 32 S., R. 23 E	1,450
Do		2	do	1,360
Do		3	do	1,340
Do		4	do	1,370
Do		5	do	1,310
Do		6	do	1,470
Do		7	do	1,345
Do		8	do	1,420
Do		9	do	
Do		10	do	
Do		11	do	
Do		12	do	
Do		13	do	
Do		14	do	
Do		15	do	
Do		16	do	
Do		17	do	
Do		18	do	
Do		19	do	
Mays		1	Sec. 28, T. 31 S., R. 23 E	1,230
Do		2	do	
Do		3	do	
Do		4	do	
Do		1	SE. ¼ sec. 30, T. 31 S., R. 23 E	1,214
Midland	Lockwood	1	NW. ¼ sec. 16, T. 32 S., R. 23 E	
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Do	do	5	do	
Do	do	6	do	
Midway Crude	Scott	1	S. ½ sec. 31, T. 31 S., R. 23 E	1,316
Do		2	do	1,328
Midway of Oregon		1	NE. cor. SW. ¼ sec. 4, T. 32 S., R. 23 E.	1,100

Oil companies and oil wells in the Midway district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Midway of Oregon	Oriental	1	NW. ¼ sec. 8, T. 32 S., R. 23 E.	1,390
Do	do	2	do	1,375
Do	do	3	do	1,350
Do	do	4	do	1,400
Do	do	5	do	1,370
Do		4	NE. ¼ sec. 7, T. 32 S., R. 23 E.	1,600?
Do		1	SW. ¼ sec. 5, T. 32 S., R. 23 E.	1,325
Do		2	do	1,195
Do		1	SE. ¼ sec. 5, T. 32 S., R. 23 E.	1,260
Midway Queen		1	Sec. 22, T. 32 S., R. 24 E.	
Do		2	do	
Monte Cristo		1	NE. ¼ sec. 31, T. 32 S., R. 24 E.	1,075
Do		2	do	1,150
Do		3	do	996
Do		1	Sec. 32, T. 32 S., R. 24 E.	836
Do		2	do	856
Do		3	do	925
Do		4	do	830
Do		5	do	816
Do		6	do	
Do		7	do	
Moore	W. B.	1	SE. ¼ sec. 25, T. 32 S., R. 23 E.	1,315
Morse et al.		1	SE. ¼ sec. 26, T. 32 S., R. 23 E.	
Do		2	do	
Mountain Girl		1	SE. ¼ sec. 22, T. 32 S., R. 23 E.	1,300
Do		2	do	1,480
Do		3	do	1,500
Do		4	do	
Do		5	do	
Do		6	do	
Mount Diablo		1	SE. ¼ sec. 26, T. 32 S., R. 23 E.	1,700
Do		2	do	1,685
New Richmond		1	SW. ¼ sec. 25, T. 32 S., R. 23 E.	1,390
Occidental	Santa Fe	1	NW. ¼ sec. 9, T. 32 S., R. 23 E.	
Occidental Queen	Moore	1	SE. ¼ sec. 25, T. 32 S., R. 23 E.	1,370
Opal	Sunset Coast	1	NW. ¼ sec. 25, T. 32 S., R. 23 E.	1,510
Do	do	2	do	
Oriental. (*See* Midway of Oregon.)				
Oskaloosa	Andrews	1	SE ¼ sec. 15, T. 32 S., R. 23 E.	1,150
Do	do	2	do	
Packard. (*See* Wilbert.)				
Packard & Tevis		1	NW. ¼ sec. 26, T. 32 S., R. 23 E.	
Do		2	do	
Paraffine		1	NE. ¼ sec. 25, T. 32 S., R. 23 E.	1,475
Do		2	do	1,490
Do		3	do	
Do		4	do	
Do		5	do	
Do		6	do	
Pierpont		1	SE. ¼ sec. 25, T. 32 S., R. 23 E.	1,440
Do		2	do	1,385
Do		3	do	
Do		4	do	
Do		5	do	
Do		6	do	
Pioneer Midway		1	Sec. 12, T. 31 S., R. 22 E.	1,258
Do		2	do	
Do		3	do	
Do		4	do	
Do		1	Sec. 18, T. 31 S., R. 23 E	
Do		2	do	
Do		3	do	
Do		1	Sec. 30, T. 31 S., R. 23 E.	1,258
Do		2	do	1,217
Do		3	do	
Do		1	Sec. 2, T. 32 S., R. 23 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	do	
Producers Guaranteed		1	SW. ¼ sec. 23, T. 32 S., R. 23 E.	1,455
Do. (*See* Amazon.)				
Rico	Neptune	1	NE. ¼ sec. 25, T. 32 S., R. 23 E.	
Do	do	2	do	1,350
Do	do	3	do	
Do	do	4	do	
Do	do	5	do	
Do	do	6	do	
Do	do	7	do	
Safe		1	NW. ¼ sec. 25, T. 32 S., R. 23 E.	1,400
Do		2	do	

Oil companies and oil wells in the Midway district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Safe		3	NW. ¼ sec. 25, T. 32 S., R. 23 E.	
Do		4	do	
St. Lawrence		1	SW. ¼ sec. 5, T. 32 S., R. 23 E.	1,325
Do		1a	do	1,260
San Francisco Oil Co		1	NE. ¼ sec. 27, T. 32 S., R. 23 E.	1,500
Santa Fe Railway		(?)1	S. ½ sec. 7, T. 32 S., R. 23 E.	1,600
Do		(?)2	do	1,500
Do		1	Sec. 6, T. 32 S., R. 23 E.	1,460
Do		2	do	1,490
Do		3	do	1,380
Do		4	do	1,420
Do		5	do	1,400
Do		6	do	1,480
Do		2	do	1,366
Do		1	S. ½ and NE. ¼ sec. 8, T. 32 S., R. 23 E.	1,350
Do		2	do	1,330
Do		3	do	1,440
Do		4	do	1,280
Do		5	do	1,310
Do		6	do	1,365
Do		7	do	1,410
Do		8	do	1,375
Do		9	do	
Do		10	do	1,270
Do		11	do	1,270
Do		12	do	1,290
Do		13	do	1,265
Do	Sioux	1	NE. ¼ sec. 8, T. 32 S., R. 23 E.	1,268
Do	do	2	do	1,370
Do	do	3	do	1,320
Do		1	W. ½ sec. 9, T. 32 S., R. 23 E.	1,200
Do		2	do	1,370
Do		3	do	
Do	Internois	1	do	1,290
Do	Equitable Petr.	1	SE. ¼ sec. 14, T. 32 S., R. 23 E.	1,140
Do	do	2	do	
Do		1	E. ½ sec. 17, T. 32 S., R. 23 E.	1,550
Do		2	do	1,425
Do		3	do	1,515
Do		4	do	1,420
Do		5	do	
Do		6	do	1,415
Do		7	do	1,475
Do		8	do	1,452
Do		9	do	1,500
Do		10	do	1,448
Do		11	do	1,475
Do		12	do	1,470
Do		13	do	1,450
Do		14	do	1,448
Do		(?)	do	1,690
Do	Spellacy	1	SW. ¼ sec. 15, T. 32 S., R. 23 E.	1,380
Do		1	E. ½ sec. 18, T. 32 S., R. 23 E.	1,850
Do		1	Sec. 21, T. 32 S., R. 23 E.	1,515
Do		2	do	1,380
Do		3	do	1,440
Do		4	do	1,500
Do		5	do	1,600
Do		6	do	1,380
Do		1	S. ½ sec. 24, T. 32 S., R. 23 E.	1,330
Do		2	do	1,350
Do	Arcata	1	NW. ¼ sec. 31, T. 32 S., R. 24 E.	1,190
Do	do	2	do	1,185
Do	Austin	1	NW. ¼ sec. 31, T. 32 S., R. 24 E.	
Do		1	W. ½ and SE. ¼ sec. 25, T. 31 S., R. 22 E.	1,254
Do		2	do	
Do		3	do	
Do		1	S. ½ sec. 4, T. 32 S., R. 23 E.	
Do		2	do	
Do		1	E. ½ sec. 26, T. 31 S., R. 22 E.	
Do		2	do	1,650±
Do		3	do	
Sioux. (*See* Santa Fe Railway.)				
Scott, C. V. (*See* Midway Crude.)				
Scott et al		1	Sec. 8, T. 31 S., R. 23 E.	
Sharp & Johnson		1	SW. ¼ sec. 6, T. 31 S., R. 23 E.	
Sheridan		1	Sec. 10, T. 31 S., R. 22 E.	
Do		2	do	

Oil companies and oil wells in the Midway district—Continued.

Name of company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Sheridan		3	Sec. 10, T. 31 S., R. 22 E.	
Do		4	do	
Standard		1	Sec. 16, T. 31 S., R. 23 E.	
Do		1	Sec. 22, T. 31 S., R. 23 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		1	Sec. 26, T. 31 S., R. 23 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		1	SW. ¼ sec. 1, T. 32 S., R. 23 E.	
Do		1	N. ½ sec 10, T. 32 S., R. 23 E.	
Do		1	E. ½ sec. 14, T. 32 S., R. 23 E.	
Do		2	do	
Do	Talara	1	SW. ¼ sec. 24, T. 32 S., R. 23 E.	1,390
Do	do	2	do	1,400
Do	do	3	do	1,395
Do	do	4	do	1,290
Do	do	5	do	1,250
Do	do	6	do	1,190
Do	do	7	do	1,115
Do	do	8	do	
Do	do	9	do	
Do	do	10	do	
Do	do	11	do	
Do	do	12	do	
Do	do	13	do	
Do	do	14	do	
Do	do	15	do	
Do		1	Sec. 20, T. 32 S., R. 24 E.	
Do		1	Sec. 28, T. 32 S., R. 24 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do	Big Four	1	Sec. 30, T. 32 S., R. 24 E.	1,160
Do	do	2	do	1,190
Do	do	3	do	1,175
Do	do	4	do	1,130
Do	do	5	do	
Sunset Coast. (*See* Opal.)				
Sunset Monarch		1	Sec. 20, T. 31 S., R. 23 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Twenty-Five Oil Co		1	W. ½ sec. 25, T. 32 S., R. 23 E.	1,640
Do		2	do	1,655
Do		3	do	1,640
Do		4	do	1,615
Do		5	do	1,535
Do		6	do	
Do		7	do	
Do		8	do	
Do		9	do	
Do		10	do	
Do		11	do	
Do		12	do	
T. and W		1	SE. ¼ sec. 25, T. 32 S., R. 23 E.	
Do		2	do	
Union	McCloud	1	Sec. 34, T. 31 S., R. 23 E.	
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Do	Sunset Road	1	SW. ¼ sec. 31, T. 32 S., R. 24 E.	
Do	do	2	do	
Do		1	Sec. 34, T. 32 S., R. 24 E.	
Do		2	do	
Union vs. Santa Fe		1	NW. ¼ sec. 14, T. 32 S., R. 23 E.	
Do		1	do	
Do		2	do	
Usona		1	NW. ¼ sec. 22, T. 32 S., R. 23 W.	
Western Crude		1	NW. ¼ sec. 4, T. 32 S., R. 23 E.	
West Side		1	NW. ¼ sec. 25, T. 32 S., R. 23 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Wilbert	Packard	1	NE. ¼ sec. 22, T. 32 S., R. 23 E.	
Do	do	2	do	
(?)		1	S. ½ sec. 7, T. 32 S., R. 23 E.	
(?)		2	do	

SUNSET FIELD.

LOCATION.

The Sunset field embraces the territory along the northeastern base of the Temblor Range, south of the line marking the change from the Mount Diablo to the San Bernardino base and meridian; and includes the southeastern part of T. 12 N., R. 24 W., the northeast part of T. 11 N., R. 24 W., the southwest part of T. 12 N., R. 23 W., and the western part of T. 11 N., R. 23 W.

GEOLOGY.

OUTLINE OF STRATIGRAPHY.

The formations involved in the geology of the developed Sunset field include coarse, semiconcretionary sandstone, 400 feet or more in thickness, believed to be Vaqueros or lower Miocene in age; 2,900 feet of siliceous and clayey shale, containing numerous thin layers and connections of fine-grained calcareous material, of Monterey or lower middle Miocene age; 1,300 feet of soft light-colored diatomaceous shale, containing layers and lenses of granitic sand and conglomerate (the latter often carrying bowlders up to 2 or 3 feet in diameter), believed to be of Santa Margarita(?) age or upper middle Miocene; a great thickness of thin-bedded sands and clays and some gravels at the base with softer, thicker bedded clays and gravels above, believed to be largely upper Miocene in age, but possibly extending into the Pliocene epoch; and, finally, alluvium and stream deposits of Quaternary age. The oil is believed to have originated in the diatomaceous shales of the Monterey and Santa Margarita(?), and to have migrated either to the included porous layers of these formations or to the sands and gravels of the underlying Vaqueros or overlying McKittrick. The productive sands in the Sunset field so far tested are entirely of McKittrick age, although, as stated later (p. 213), it is the belief of the writers that commercial quantities of oil are contained in sands in the base of the Monterey or top of the Vaqueros in certain structurally favorable localities in this field.

STRUCTURE.

The Sunset field is located on the Thirty-five and California Fortune anticlines and subsidiary flexures, all of which are developed on the great folded monocline on the northeast flank of the Temblor Range. The southeastern end of the field extends into the region where the monocline bends from a southeasterly to an easterly strike. The general geology and structure of the region is shown on Plate I, while the details of the developed areas are shown on Plate IV.

OIL SANDS.

Zone B.—In mapping the underground geology of the developed territory the top of the main oil sand or zone (zone B) has been chosen for contouring, with mean sea level as the datum plane. It must be borne in mind continually, however, that the point chosen in each well does not represent the top of a continuous bed or layer, such as the term "sand" means in many of the eastern fields and occasionally in the California districts, but rather the point above the base of the McKittrick formation, where the saturation of the sandy layers or lenses with petroleum is complete enough to render their exploitation profitable. It is possible to trace certain particular layers from well to well over short distances, but it is impossible in this field to carry such a correlation for any great distance. The reason for this is obvious when one studies the oil-bearing formations in outcrop, for it is then seen that the formation consists of layers, or, more properly speaking, lenses, of gravel, sand, and clay or shale of limited extent. As in some of the other fields, the impregnated zone above the unconformity generally increases in thickness with depth, so that the horizon contoured is not parallel with the surface of unconformity, but gradually rises away from it with depth. The average rate of increase of the thickness of the zone or distance from the contoured horizon above the unconformity in the central part of the productive field is between 100 and 200 feet per mile. The variation in thickness of the oil zone is not regular, by any means, and it is not uncommon to find a comparatively deep well that contains, according to its log, a less thickness of oil sand than an adjacent shallower one. This condition is accounted for, at least in part, by the personal factor brought in by the drillers who record the logs; but in other instances it is doubtless due to thinning of porous layers, etc.

Zone B varies in thickness from 12 to 140 feet and averages about 60 feet in the northern part of the field; is 12 to 250 feet thick (this latter figure doubtless including much interbedded shale) and averages over 150 feet in the central area; and is 15 to 40 feet thick and averages nearly 20 feet in the southeastern portion. The zone consists of medium-grained to coarse sand and pebbly layers containing cobbles up to 8 inches in diameter and intercalated minor shale or clay partings. The productivity and quality of the oil on the two sides of a parting are in some places noticeably different. The oil is said to occur locally in shale. The sands are usually of quartz grains, and the pebbles and cobbles are mostly of granite, sandstone, or siliceous Miocene shale; some diabase, black quartzite, and black slate also occur as pebbles or cobbles. The sands are often more or less soft or incoherent, and as a result flow out of the wells with the oil, often making up 30 to 60 per cent of the gross yield.

Zone A.—Zone A includes the gas, tar, and oil sands intercalated in the relatively much thicker shale or clay beds lying above the more richly impregnated and commercially important sands of zone B. Zone A varies in thickness from about 250 feet in the shallower wells to as much as 500 feet (exceptional) in the deeper wells of the central portion of the field. In some of the shallower territory toward either end of the field zone A consists only of one or two thin tar sands. The individual petroliferous sands of this zone, from one to eight or possibly more in any particular well, are 5 to 35 feet thick, and vary in composition from medium to coarse grained and pebbly quartz sand; cobbles occur more rarely than in zone B. The gas and tar sands are usually found in the upper portion of the zone, while some of the lower sands or sandy shales carry minor and possibly even commercial quantities of oil. In some of the wells in the central part of this field good showings of 16° and 18° Baumé oil are said to have been encountered in the lower part of zone A. Water sands are also associated with the petroliferous sands in zone A, especially in the portions of the field overlying synclines. The lowest oil or tar-bearing sands in zone A are usually separated from zone B by 20 to 60 feet of stiff blue clay, an ideal landing place for casing.

Beds above zone A.—The beds above zone A consist of shale and clay with minor amounts of sand and gravel, the latter usually occurring near the surface and being of stream origin. The sands of this part of the formation often carry water, and very rarely a little tar or gas.

Beds below zone B.—The beds below zone B consist almost entirely of blue and brown shale with occasional sand layers or lenses, which sometimes carry water. This shale is a part of the Miocene shale formations (Santa Margarita(?) and Monterey) exposed in the hills southwest of the developed territory, and occurs in an unconformable position below the McKittrick formation, in the base of which is zone B. The Miocene shale formation is several thousand feet thick, and as the wells in this developed territory penetrate the upper beds only, it is almost certain that they would never be able to drill through it into the underlying sands of the Vaqueros (lower Miocene) in the present developed part of the field.

WATER SANDS.

Water occurs at one place or another throughout practically the whole thickness of strata in this field so far penetrated by the drill. It is nearly always present in the sands above zone A, although in some of the wells in the northern part of the field it is either lacking or present only in small quantities. The first water is encountered at a depth of 80 to 450 feet, depending on location, the deepest occurrences generally being in the synclines. Water is particularly abundant in the areas overlying synclines, such as the northern part of sec. 2, T. 23 N., R. 12 W., and the syncline near Hazelton, where the strike bends from southeast to east. In this latter area zone A contains considerable quantities of water, usually charged with sulphur. The water in the beds above zone B is highly mineralized, and consequently often useless. It sometimes flows, but more often rises only a short distance in the holes. The greatest flow of water yet encountered in the field comes from Northern No. 1, from a sand that either just overlies or is a part of zone B. This water is warm and flows from the well under a considerable pressure, probably due to gas. It is utilized for development purposes by some of the companies. Water is reported immediately under zone B in most of the wells that pass entirely through the oil zone. It is believed that this condition prevails throughout much of the field. Deep wells penetrating the Miocene shale below zone B generally strike artesian flows of warm, more or less mineralized, water in the intercalated sands. Some of these wells reach a depth of 1,700 feet and yield over 3,000 barrels per day. In one well the water comes out with a temperature of 120° F. Water from these deep wells, after passing through a salt precipitating process, forms a part of the domestic supply for the field.

PRODUCT.

The hydrocarbon products of the Sunset field consist of heavy tar, oil varying in gravity from 11° to about 20° Baumé, and gas. The tar occurs in springs along the outcrops of the oil sands, in certain exposures of the upturned petroliferous siliceous shales in the southeastern part of the field, and in certain layers or lenses encountered in the wells in zone A.

The oil is black and the heavier qualities very viscous. The heavier oil, averaging from 12° to 13° Baumé, occurs in zone B in the shallower wells which are located at either end and along the southwestern edge of the field. The lighter oil, 13.5° to 20° Baumé, is produced by the deeper wells, especially those in the northern part of the field. The lightest oil occurs in the deeper wells at the northern end of the field. Oil said to test 16° to 18° Baumé occurs in moderate amounts in a series of shales and fine sands in the base of zone A, but none so far is utilized in any of the wells.

Gas of a good quality occurs under great pressure with the oil in zone B, and also in minor amounts in some of the sands of zone A. Owing to the peculiar manipulation of the wells it is more or less difficult to save the gas, and much of it is wasted.

As indicating the great pressure under which the gas is confined in the deeper wells, it is stated that in the central part of the field a string of tools became stuck in a 9⅝ inch casing in a well 880 feet deep, and the gas pressure at the bottom was great enough to force tools and casing upward in the well until the casing was chained down to the derrick floor. Assuming 22 pounds per foot for the weight of the casing, 3,000 pounds for the weights of the tools, the total weight raised by the gas was over 22,000 pounds, not including the friction between the casing and walls of the well overcome in the operation, which must have been considerable. The pressure was probably between 500 and 800 pounds per square inch.

PRODUCTION.

The wells vary in production from 4 to 25 barrels per day for the shallower holes yielding heavy oil to over 400 barrels per day for the deeper ones producing a better grade. The average daily production for the wells in the northwest portion of the field is 25 to 40 barrels; in the central and northern areas 75 to 400 barrels, and in the southeastern synclinal portion 50 to 100 barrels. Contrary to the rule in most fields, some of the wells in this one increase their production after operation for awhile, this condition resulting from a gradual loosening up of the oil sand, which packs around the casing, by intermittent agitation of the casing. Those wells which start with a heavy production (said to have been at the rate of 3,000 barrels per day for a short while in at least one of the wells) usually fall off rapidly during the first few days of their operation, but still have been known to maintain a yield of 200 to 300 barrels for a period of two or three years at least. Much sand accompanies the oil, sometimes as much as two-thirds of the gross yield of the well being sand. One well alone produced over 110,000 cubic feet of sand in about four years and another has yielded almost as much in two years. The yield of sand gradually decreases with the age of the well, but at no time entirely ceases. The production of sand is less toward the southeast and north, some wells in these parts of the field yielding only moderate amounts with the oil.

METHODS.

Depth of wells.—The wells in the Sunset field vary from 350 to over 1,900 feet in depth.

Drilling.—The method of drilling in this field is similar to that generally in use in the other California fields, the standard rig being used. An innovation in the method of facilitating drilling through the troublesome cobble beds was the use of dynamite to break up the bowlders in the Ruby wells. It is said that the experiment was highly successful.

Shutting off water.—The water above zone A in the wells is usually shut off with the first string of casing in the clay or shale beds just above the top of zone A, or occasionally in its upper portion. The second string is generally landed in the clay between zones A and B, although it is not unusual to carry the second string into the oil sand. No method has so far been devised to successfully shut off the big flow of water encountered at the top of zone B in the wells in the northeast corner of sec. 12 and the southeast corner of sec. 1, T. 11 N., R. 24 W.

Operation of the wells.—The peculiar conditions—soft sand accompanying the flowing oil in great quantities, heavy oil, and strong gas pressure—make the problem of well operation in this field a serious one. A method of handling the wells which has proved highly successful was discovered several years ago by accident and is said to have been first used in Sunset Monarch well No. 3. This method consists in intermittently agitating the sand within or below the casing which penetrates the oil sand by means of a smaller "agitating string" (usually a 7⅝-inch string within a 9⅝-inch casing). If the sand is thus kept loosened by agitation, the gas pressure is strong enough to cause the well to flow. When the gas pressure weakens compressed air is forced down the agitating string, usually with successful results. It has been found impracticable for various reasons to pump oil containing so much sand, and the agitation method has therefore been the salvation of the field.

Separation of oil and sand.—As has been mentioned at many places throughout this report, the oil in the Sunset field is accompanied by large quantities of sand. To separate the oil and sand large earthen reservoirs are built around each well, and the floor of the derrick erected from 8 to 12 feet above the bottom of the reservoir. The oil and sand are run into the reservoir through a pipe or open trough which can be directed to any part of the basin, and the product is allowed to flow out and stand. The sand collects in cones under the discharge pipe, while the oil settles to the lower part of the basin and is conducted away to storage tanks or reservoirs. Much of the oil is so heavy and viscous that artificial heat often has to be applied to it for facility in handling, especially in cold weather.

LOCAL AREAS OF SUNSET FIELD.

CALIFORNIA FORTUNE—J. B. & B.—SUNSET MONARCH AREA.

Location.—The area denoted by the heading includes wells in the southeast corner of sec. 28, the northeast corner of sec. 33, the southwest corner of sec. 27, all of secs. 34, 35, and 36, T. 12 N., R. 24 W., and a small area in the northern part of the NW. ¼ sec. 2, T. 11 N., R. 24 W. Among the principal properties lying within the area are the Union, California Fortune, Acme, and Sunset Monarch. The wells are situated on the northeast flank of the California Fortune anticline, on the Thirty-five anticline, and on the subsidiary wrinkles between these two.

Zone B.—Zone B varies in thickness from 25 to 140 feet, and averages probably about 60 feet. The zone is reported in most of the areas as a continuous sand, although in a few a shale or clay parting a few feet in thickness sets off a portion of the sand at the top or bottom, the isolated portion usually carrying oil either lighter or heavier than the main body of the sand. A typical section of zone B from a well in the NW. ¼ sec. 34 is as follows:

Typical section of zone B in well in the NW. ¼ sec. 34, T. 12 N., R. 24 W.

	Feet.
Coarse sand	25
Cobbles	4
Medium-grained sand	10
Cobbles	4
	43

The sand is usually coarse granitic in texture, with grains often approaching the size of wheat. The conglomeratic layers often carry cobbles up to 8 inches in diameter; these are mostly quartz and granite, but black slate and considerable quantities of siliceous shale are also found in the coarse beds.

Zone A.—Zone A extends 260 feet or less above zone B in the area of the southeast corner of sec. 34; northwest of that point zone A is not a well-developed feature, many of the well logs indicating no tar or oil sands above zone B, and it is possible that the California Fortune and adjacent wells may be obtaining their oil from beds the equivalent of zone A farther southeast. This is a point that will be settled only after exploitation of the territory in the center of sec. 34. The contours are drawn with the assumption that the productive sands are zone B, the basal beds of the McKittrick formation, which seems the most plausible hypothesis. Zone A consists of one or more sands, 5 to 10 feet through, carrying gas, tar, or a little oil, interbedded in much greater thicknesses of shale or clay. Some of the sands are dry or carry only traces of hydrocarbons. A little water-carrying sand is sometimes interbedded in the upper part of the zone in the Phœnix syncline.

Beds above zone A.—The beds above zone A consist largely of blue clay and shale, in which occur minor sands, water sands, shells, and layers of cobbles, the latter believed to be stream wash where they occur near the surface.

Water sands.—The water sands in the area are unimportant except in the region of the Phœnix syncline, where one and sometimes two or three occur above the lowest tar sands. A water sand 5 to 10 feet through usually overlies zone A, but is not encountered in a considerable number of the wells.

Product.—The oil in this area is black and heavy, varying in gravity between 11.5° and 15° Baumé, averaging about 13.5°. Much gas accompanies the oil, and gas is also encountered in zone A above the productive beds.

Production.—The initial individual production of the wells, especially of those first drilled in any particular piece of territory, has been known to reach from 400 to 600 barrels per day for a short time. The average production after operating is probably not over 25 to 40 barrels for the whole area. Much gas and sand accompany the oil, the latter sometimes being in excess of the oil, especially during the early part of any well's operation. In so far as they have been tested the wells hold to a fairly constant output after the initial decline.

Methods.—The productive wells of the area are from about 500 to 925 feet deep. Some of them flow without perforation from the casing stopping in the oil sand, but most of the wells are perforated and pump. Water is usually shut off below zone A (tar sands) where plenty of good shale or clay is available for landing casing.

Typical logs.—A log typical of the wells in the northwestern section of the area is as follows:

Log of well in the NW. ¼ sec. 34, T. 12 N., R. 24 W.

	Feet.
Soil	6
Sand	45
Hardpan	56
Cement sandstone	80
Blue clay	90
Blue sandstone and clay	105
Blue clay	136
Blue clay	174
Blue shale	200
Hard shell	202
Blue shale	231
Shale or clay	281
Sand	286
Gritty blue shale	315
Soft, sandy blue shale	365
Blue clay	379
Blue shale	400
Blue clay	417
Soft sandstone and blue shale	438
Blue shale	455
Soft sandy blue shale	477
Blue shale	483
Brown shale	489
Blue shale	506
Oil sand	516
Hard shell	518
Oil sand	531
Hard shell	534

	Feet.
Oil sand	537
Hard shell	538
Oil sand	560
Cobbles and oil sand	563
Oil sand	588
Oil sand and cobbles	589
Oil sand	610
Oil sand and cobbles	611
Oil sand	660. 5
Oil sand and cobbles	664
Oil sand and brown shale	672
Oil sand	691
Oil sand and brown shale	697

Two logs typical of wells in the southwestern section of the area follow:

Log of well in SE. ¼ sec. 34, T. 12 N., R. 24 W.

	Feet.
Yellow sandy clay	130
Blue clay	142
Purple sand rock	152
Blue sandy clay	197
Blue sand	218
Sticky blue clay	250
Hard sandstone	270
Blue clay	300
Blue clay, sandy	365
Tar sand, not much oil, very fine	370
Blue clay	395
Blue joint clay	415
Oil sand, not much gas	430
Hard shell	431
Brown shale, gas with oil	442
Blue and brown shale, very cavy	500
Blue joint clay or shale	550
Oil sand, much gas	586
Landed on shell	585

Log of well in NW. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Wash and sand	90
Blue shale and sand (water at 376)	376
Blue shale	412
Blue clay	432
Tar sand and blue shale	536
Blue clay	566
Blue shale	593
Brown shale and sand with oil	617
Oil sand	634
Brown shale	638
Oil sand	740
Oil sand and shale	756

ARCOLA—OCCIDENTAL—BARRETT AREA.

Location.—This area includes the wells in sec. 2, T. 11 N., R. 24 W., with the exception of those in the extreme northern and eastern portions of the section. Among the wells described are those formerly known as the Santa Rosa and Occidental (now belonging to the Sunset Monarch), the Arcola, and the Barrett wells in the center of the SE. ¼ sec. 2, belonging to the Union. The wells are on the northeastern flank of the California Fortune anticline, on the Sunset Monarch anticline, and in the syncline between the two anticlines. The Sunset Monarch anticline is local in extent and has been located principally upon evidence furnished by well logs. Its exact relations and character are unknown, and a fault may possibly be associated with it.

Zone B.—Zone B is from 20 to 140 feet thick, the second figure undoubtedly including considerable intercalated shale. The sand is of quartz grains and coarse for the most part, and some of it contains pebbles of granite, blue shale, quartz, and siliceous shale exhibiting impressions of ostracods. It is usually incoherent and much of it accompanies the oil, especially immediately following the inception of the wells. Zone B is overlain by sandy shale and shell, and overlies the brown shale which occupies the hills west of Sunset. Water is indicated as occurring at the base of zone B in only one log in this area, and that is the log of a well near the axis of the Sunset Monarch anticline, in a region where the strata are probably much disturbed.

Zone A.—Zone A is usually less than 200 feet thick, although near the center of sec. 2 some oil and tar sands are encountered as much as 370 feet above the top of zone B. Zone A contains from one to three petroliferous sands from 5 to 23 feet thick, interbedded with clay and numerous hard shell layers. Heavy oil or tar and considerable gas is usually found in the sands of this zone; in one well near the center of sec. 2 the uppermost sand (here 8 feet thick) of zone A yielded oil in great enough quantity and under pressure sufficient to cause it to flow over the casing a short while. This sand was never thoroughly tested, however.

Beds below zone B.—The beds below zone B, which, from surface evidence, are believed to lie unconformably with it, consist almost entirely of blue and brown shale with occasional lenses of sand. Many of these intercalated sands carry water and some of them gas. The steep angle at which the strata of this underlying shale rest lessens the probability of reaching the oil sands which lie at the base of the Monterey shale in wells of reasonable depth.

Beds above zone A.—The strata overlying zone A consist largely of blue clay and shale, with some sand, water sand, and cobble and shell layers, as in the other areas in this field. The cobble beds are mostly encountered near the surface and many of them probably represent surface wash.

Water sands.—Water occurs in sands, usually just above zone A or under the first tar sand, at 140 to 400 feet below the surface. They are from 5 to 15 feet in thickness, more often the former, and are usually coarse-grained. In no well were more than two water sands reported as occurring above zone A. Water does not occur immediately under zone B in any of the wells tested. The waters in the beds overlying zone B are all of a very poor quality, being highly mineralized.

Two wells within this area have penetrated to considerable depths below zone B, and each secured a supply of fairly good water. In the well in the southeast part of the NE. ¼ sec. 2 water occurs at about 500 and 1,000 feet below the surface, at the latter horizon in considerable quantities. The well in the northern part of the SW. ¼ sec. 2 taps water sands at about 500 feet and also at 1,500 feet, the latter zone consisting of several sands yielding about 3,000 barrels per day of sulphur water, which comes from the well under artesian head at a temperature said to be 120° F.

Product.—The wells of this area yield black oil varying in gravity from 13° to 16° Baumé, with an average of between 14° and 15°. The only regularity noted in the variation is that the thicker and coarser sands yield the heavier oil. It is said that the oil occurring in the sands of zone A is usually lighter than that found in zone B, although none of these upper sands are utilized. Much gas accompanies the oil, as in the other areas of this field.

Production.—The individual production varies from 10 to 100 barrels per day, averaging about 40 barrels, the deeper wells on the southwest side of the Sunset Monarch flexure being the more productive. Sand in large quantities usually accompanies the oil. The wells near the axis of the Sunset Monarch anticline or flexure are either nonproductive or the least productive in the area.

Methods.—The depth of the wells passing only through the productive sands (zone B) varies from 350 to 940 feet; some water wells passing through the oil sands and down into the underlying shale formations attain a depth of 1,500 to 1,700 feet. The wells flow as long as the gas pressure is sufficient to force out the oil and sand; most wells, however, soon lose their pressure and must be pumped. Sand interferes with the pumping and makes operation expensive. The water is usually shut off between zones A and B, but occasionally above zone A; 11⅝-inch or 9⅝-inch casing is usually the largest used.

Typical logs.—A log typical of the wells in the central part of the area is the following:

Log of well near the southwest corner of the NE. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Surface	80
Blue clay and sand	120
Sand rock	128
Clay and sand	260
Sand rock	275
Hard clay	295
Gas sand	300
Oil sand	308
Water sand	311
Blue clay	340
Brown sand, with water	358
Greasy shell	368
Water sand	376
Blue clay	393
Blue clay and slate	433
Blue clay	441
Fluffy sand	448
Blue shale	500
Brown shale	660
Oil sand	708

A log typical of the wells in the northwestern portion of the area is as follows:

Log of well near the center of the NW. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Surface yellow clay and slate	180
Blue clay	195
Yellow sand	205
Blue clay, very cavy	230
Sand and shale	350
Blue shale	270
Hard shell and sand	278
Blue clay	305
Hard shell	308
Blue shale	324
Sandy shale	336
Hard shell	348
Blue shale	360
Shell	362
Blue clay	375
Lime rock	377
Blue shale, with hard shell and sulphur	398
Blue sand, with water	403
Blue clay (cavy)	412
Very hard shell	415
Blue clay	430
Brown shale and oil sand	440
Blue shale and oil sand	465
Blue shale	551
Soft shell	556
Oil sand	576
Brown shale	620

McCUTCHEON—MONTE CRISTO—RUBY AREA.

Location.—This area comprises the eastern part of the NE. ¼ sec. 2 and the NW. ¼ sec. 1, T. 11 N., R. 24 W., and includes the wells of the Sunset Rex, McCutcheon, United Crude, Transport (now Sunset Monarch), Monte Cristo, and Ruby oil companies. The wells occupy the flanks of the Phœnix syncline, which plunges in a southeasterly direction through the middle of the north line of sec. 2 and the flanks of the Thirty-five anticline.

Zone B.—The productive strata included in zone B vary in total thickness from 40 to 135 feet, the greater thickness usually occurring in the deeper wells. The individual sands of zone B become thinner and more numerous toward the east down the dip, the productive zone thickening by the intercalation of brown shale. A typical section of zone B shows five or six alternations of brown shale and oil sand beds, the latter often carrying cobbles of considerable size. The sand is largely granitic, coarse, and more or less incoherent, and flows out with the oil, although in less quantities than from the wells farther south. The cobbles occur toward the top of the zone in the southern wells, and an unusual amount of gas seems to be associated with the oil in the cobble-bearing strata. The oil is said to occur often in shale in the deeper wells, and this product is said to resemble mud. In the northern part of the area the richest sand occurs near the top of zone B.

Zone A.—Zone A usually embraces the strata for about 800 feet above the top of zone B, and even a little higher in some of the deeper wells. The beds carrying tar are more in evidence in the southern or shallower wells, water appearing to supplant the tar in certain of the beds toward the north end. The sands are usually 8 to 20 feet thick and occupy only a small percentage of the section included within the limits of the zone. Some of the sands of zone A, especially the lower ones, show indications of oil in commercial quantities, but none have been adequately tested so far as the writers are aware. Zone A and zone B are usually separated by 40 to 250 feet of blue clay or shale. This great variation in the thickness of nonpetroliferous beds between the two zones is conclusive evidence of the extreme localization of deposition in this general region.

Beds above zone A.—The beds above zone A consist of blue clay with minor amounts of intercalated sand and water sand. The sand increases in importance toward the northwest, but even in those logs showing the most sand the shale still predominates. Cobbles are reported in the upper beds in only two or three wells, and these in the northern part of the area.

Water sands.—The first water sand is struck at depths ranging from 130 feet below the surface in the shallower wells to over 500 feet deep in the deeper ones. The water sands occur as far down as within 40 feet of the top of zone A, and in some instances they are even found below the uppermost tar sand. An unusually big flow of water is reported in sands just above zone A in a well in the E. ½ NE. ¼ sec. 2. The water sands are from 5 to 28 feet in thickness, and occur as lenses rather than as beds having a wide extent. Water is reported in a bed just below what is believed to be zone B (the productive zone) in one of the deep wells near the center of the E. ½ NE. ¼ sec. 2. This occurrence is very significant as indicating the danger of too deep drilling in this particular part of the field.

Product.—The oil produced in this area is black and varies from 13° to 20° Baumé in gravity, the lighter oil occurring in the deeper wells in the eastern part of the area. Much gas accompanies the oil, as in other parts of the field.

Production.—Some of the wells in the area having a high initial production drop rapidly after a few hours or days, while others with a low initial output increase it with age. One of the deeper wells is said to have flowed for a few hours at the rate of 2,000 barrels per day, but soon dropped to a daily run of 500 barrels and then to 200 barrels, which it still holds when in good condition. Another well at the eastern end of the area started with a production of 3,000 barrels per day, but at the end of ten days had dropped to a flow of 600 barrels. Wells in the western part of the area having an initial daily production of 35 to 50 barrels produced from 75 to 90 barrels after a few weeks. The oil sand penetrated by these wells appeared to be dry during the course of the drilling. The average individual initial production for wells in this area is between 350 and 500 barrels per day; the average daily production is probably 150 barrels per well.

Methods.—The wells in this area vary in depth from about 700 to over 1,400 feet. They are operated in the same manner as those farther south—that is, by agitation of the inner tubing, the oil flowing out between the inner and outer strings of casing, and by pumping. In some of the wells it takes some little time to "liven up" the oil sand and start it flowing. Dynamite has been used successfully in some of the wells in this area to shatter the cobbles and bowlders encountered in drilling. This use of explosives is not to be compared with its use in the fields of the Eastern States, where the rocks containing the oil are blasted to increase the flow of the oil.

Typical logs.—A typical log of one of the shallower wells in this area is as follows:

Log of well in the southern part of the NE. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Surface	55
Gypsum	137
Blue sandy clay	332
Dry sand	340

	Feet.
Blue clay, water	387
Blue clay and shells	430
Oil sand	438
Blue clay	474
Dry sand	476
Blue clay	484
Hard shell	487
Blue clay	500
Hard shell	502
Blue clay	507
Hard shell	508
Brown and blue clay	525
Shell	526
Oil sand	538
Blue clay	546
Oil sand	555
Blue clay	608
Hard shell	609
Blue clay	614
Oil sand	616
Blue clay	633
Shell	635
Blue clay	678
Oil sand	790

A typical log of one of the deeper wells of the area is as follows:

Log of well in the northern part of the NE. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Yellow earth	85
Yellow clay	100
Cement gravel	150
Blue shale, clay, and shells	495
Sand	510
Water sand	515
Hard shell	525
Blue clay	560
Sand	570
Blue clay	610
Sand	615
Blue mud	650
Sand	660
Blue mud	680
Clay	795
Sand with oil and gas	805
Blue clay and shell	850
Sand	855
Blue clay and shale	880
Brown shale	905
Tar sand and shale	910
Blue shale	1,017
Brown shale, rotten	1,185
Oil sand	1,220
Brown shale	1,227
Oil sand	1,233

ADELINE—GATE CITY—FULTON AREA.

Location.—This area includes the eastern part of the SE. ¼ sec. 2 and the western part of the SW. ¼ sec. 1, T. 11 N., R. 24 W., and comprises property operated under the following companies: Adeline, Gate City, Fulton, and Maricopa (now belongs to Gate City). Most of the wells are on the flanks of a small dome or quaquaversal which is developed on the side of the California Fortune anticline.

Zone B.—Zone B is believed to be about 40 to 100 feet thick in this area, although thicknesses of 262 and 271 feet are noted for it in the logs of two widely separated wells. It is believed that these last thicknesses include large amounts of intercalated shale, and that the first figures should be taken as representing the range of thickness in the wells. The following section of the productive zone is believed to be characteristic of zone B:

Section characteristic of zone B, Adeline-Gate City-Fulton area.

	Feet.
Overlying beds	715
Shale with gas	745
Oil sand	755
Shale	777
Oil sand (good)	780
Shale	790
Oil sand (very rich)	800
Shale	810
Oil sand (good)	815
Shale	816

The sand varies from fine-grained to coarse or pebbly, and carries some cobbles of considerable size. The sand consists of quartz, black slate, limestone, and siliceous shale grains, with pebbles of all these and also of granite. The oil zone is in some places divided into two parts by a hard shell, and in these wells the productivity of the portion below the shell is usually greater than that above. The thinner sands in zone B become dry in the shallower wells.

Zone A.—Zone A is usually between 240 and 300 feet thick, though in the deeper holes it extends as high as 540 feet above the top of zone B. The zone consists of alternating moderately thin beds of clay or shale and medium to coarse grained sand, the latter usually, and the shale rarely, carrying gas. Heavy oil or tar, or moderate amounts of oil, the latter mostly in the lower sands, occur in the zone. Water occurs rarely in zone A except in the shallower wells, where tar and water (the latter probably surface water) are reported closely associated. One of the wells in the western part of the SW. ¼ sec. 1 showed a thin stratum of sand in zone A carrying a little water thoroughly charged with sulphur. In one or two other wells where zone A is exceptionally thick a water sand occurs below the uppermost tar sands. No water whatever occurs in the lower or even the middle part of the zone. The lowest oil or tar sand in zone A is usually separated from zone B by about 40 to 60 feet of clay or shale, although in some wells, especially the shallower ones, tar sand or dry oil sand is reported as immediately overlying the productive zone.

Beds above zone A.—The strata above zone A consist largely of blue clay with occasional sand, water, and shell layers, and some gravel beds near the surface. Traces of tar and some gas are reported rarely in the upper beds, and seem to represent isolated lenses of hydrocarbon-bearing sands.

Water sands.—The first water is encountered in the shallow and moderately deep wells at 80 to 180 feet below the surface; in the deeper wells at 250 to 350 feet. No water is reported in the wells near the center of the NE. ¼ SE. ¼ sec. 2. The lowest water sand in the beds above zone A is usually separated from zone A by 40 to 60 feet of clay, although in many of the wells no water is reported below the first water sand, which may be several hunderd feet above zone A. Sulphur water is reported as occurring below the top of zone A in one well, and in one or two others water sands in zone A are mentioned in the logs; these occurrences are believed to represent isolated lenses of water sand. Only one deep well has been put down in this area, and that penetrates about 1,100 feet of blue shale, with occasional thin sands and shells below zone B before reaching important water sands. The water sands are overlain by 50 feet of hard sand shell. This well is about 1,700 feet deep, and its initial production of water was about 800 barrels per day.

Product.—Heavy tar or asphaltum occurs in the shallower wells (not operating) in this area; oil of 11.5° Baumé gravity in the moderately shallow ones and oil up to 13.25° in the deeper ones; the average for the area is probably about 12.5°. The oil carries considerable gas, and for this reason drops slightly in gravity upon standing.

Production.—The wells vary in initial production from 25 to over 800 barrels per day, the latter being very unusual. Most of the wells drop to a daily average of 75 to 200 barrels, flowing under their own gas pressure, and this is sometimes raised to over 250 barrels by the use of compressed air. Much sand accompanies the oil from the wells, as high as 50 to 70 per cent of the product during the early life of the well being sand. According to the estimates of the writers, based on the sand in the sump reservoir, Adeline well No. 13 has produced over 110,000 cubic feet of sand since it began flowing in February, 1904. Large quantities of gas are produced by the wells in this area, but the peculiar way of operating the wells precludes the profitable saving of much of the gas.

Methods.—The productive wells in this area are from 400 to 1,060 feet deep. One water well which passes into the shale formation underlying zone B attains a depth of about 1,700 feet. The wells are kept flowing by agitating the sand with the inner casing. Some of the wells are also operated by means of compressed air, which materially augments the production under normal gas pressure.

Typical logs.—The following is a typical log of a well in the western or shallow part of the area:

Log of well in the north-central part of the SE. ¼ sec. 2, T. 11 N., R. 24 W.

	Feet.
Surface	120
Blue clay	275
Tar sand (no oil)	295
Blue clay	296
Shell	301
Tar sand (no oil)	347
Shell	348
Blue clay	353
Shell	354
Blue clay	365
Brown shale	372
Gravelly tar sand (water)	380
Blue clay	391
Gravelly oil sand	410
Blue clay	413
Brown shale	420
Blue clay	424
Brown shale	448
Blue clay	480
Brown shale	490
Blue clay	506
Brown shale	509
Blue clay	548
Coarse sand and gas	558
Granite bowlders and gas and oil	564
Coarse gravel and sand	580

A typical log of the wells in the deeper territory is as follows:

Log of well near the center of the SW. ¼ sec. 1, T. 11 N., R. 24 W.

	Feet.
Surface	323
Water sand	325
Shale and clay	368
Shell	373
Clay	375
Water sand	390
Clay	405
Shale and clay	470
Shale	475
Clay	480
Shell	485
Clay	535
Shale	552
Oil sand, tar sand, gas, and oil	561

	Feet.
Shale	580
Clay	582
Shale	615
Clay	625
Oil sand, oil, and gas	635
Shale and shells	655
Shale	658
Heaving sand and much gas	668
Oil sand	685
Clay and shells	700
Shale	720
Oil sand	722
Shale	752
Oil sand	760
Shale	772
Hard shell	775
Oil sand, most of gas found here	795
Oil-bearing shale	883
Shale and oil sand	904
Oil sand (coarse)	1,067

FULTON—SNOOK—LADY WASHINGTON AREA.

Locations.—This area comprises the SE. ¼ and the eastern part of the SW. ¼ sec. 1, the northern part of sec. 12, T. 11 N., R. 24 W., the northern part of sec. 7, and the southwestern part of sec. 6, T. 11 N., R. 23 W. The wells are operated by the following oil companies, among others: Fulton, Kern Sunset, New Center, and Walter Snook.

Zone B.—Zone B varies from 12 feet thick in the shallower wells to 140 feet thick in the deeper. This zone is represented as a continuous oil sand in all the logs examined, but it is believed to consist of alternating sand and clay beds, the former largely predominating. The sand is generally incoherent and consists mostly of medium to coarse quartz grains, and in many places carries pebbles and cobbles of granite, basalt, and siliceous shale. Fragments of the oil sand containing fossil seashells are sometimes brought up in the bailers. A hard shell usually caps zone B, although a clay layer is reported in some of the logs.

A well in the southeastern part of sec. 1, T. 11 N., R. 24 W., penetrates nearly 300 feet of sand showing traces of oil, just below the sand carrying the heavy water flow of this particular locality. It is believed that this sand is the equivalent of zone B in the wells to the southwest. Owing to the thin and soft nature of the brown shale overlying this oil sand and separating it from the sand carrying the heavy flow of water it seems improbable that it will be possible to save the oil which it may contain.

Zone A.—The zone of oil, tar, and gas sands usually begins about 260 feet above the top of zone B; the lowest petroliferous layer in zone A is generally separated from the top of zone B by 60 to 80 feet of brown or blue clay or shale. The number of individual petroliferous sands or sand lenses in zone A is from two to seven in different wells. These are separated by layers of clay, shell, or shale much thicker in the aggregate than the sand beds. The individual sands are from 3 to 33 feet thick in the wells and vary in grain from fine to coarse sand, and gravel, carrying cobbles up to 8 inches or more in diameter. Some of the sands are dry; others contain a heavy tar; and some, notably those in the lower part of the zone, carry oil in considerable quantities. Nearly all the sands contain more or less gas. A series of alternating sand and shale layers, 36 feet thick, the top of which was 110 feet above the top of zone B, is said to have yielded enough 18° Baumé gravity oil where the sand was first penetrated to flow over the top of the casing for a short time. This sand was never thoroughly tested, but the occurrence indicates the possibility of obtaining commercial quantities of oil in other sands besides those of the main oil zone, zone B. Water occurs in zone A about 180 feet above the top of zone B in the wells near the middle of the west line of the NE. ¼ sec. 12, but is not encountered in the same zone in any of the other wells of the area whose logs were examined by the writers.

Beds above zone A.—The beds above zone A consist largely of blue clay and fine-grained sandstone in thin alternating beds and zones and minor amounts of coarse gravel and conglomerate, the former usually at or near the surface. Water occurs in some of the sands and occasionally traces of gas or oil are found in them.

Water sands.—In addition to the first water sands, which occur between the surface and 250 feet, there are usually two or three other sands carrying water in the formation above zone A. In one well at the south end of the area the first water is reported at 560 feet. The lowest water sand is in some places separated from zone A by only 20 feet of blue clay, and it is usually in this clay that the upper waters are shut off. The water sands vary from fine-grained to conglomeratic and range from 2 or 3 feet up to 10 feet in thickness. The water is highly mineralized and useless for most purposes.

One of the most remarkable flows of water ever encountered in an oil field in California was that struck by Northern No. 1. At about the point where zone B (the productive sand) was expected in this well the drill went through a hard shell into a dry oil sand, but got no farther, as at this point a heavy flow of water—estimated at from 20,000 to 50,000 barrels per day—came into the hole. This flow diminished somewhat, but at the present time (November, 1909) is very strong. The same water is encountered at the same horizon in a near-by well, which, upon passing through the water sand and a thin underlying brown shale layer, entered about 300 feet of oil sand, supposed to be zone B. It is the belief of the writers that this water comes from a more or less local lens of sand immediately overlying zone B, and that it derives its pressure from gas which has access to the lens from some of the adjacent petroliferous layers. It is inconceivable that the water is under an artesian head, because it is not encountered in any of the wells penetrating the same zone farther southeast and higher up on the dip. The great amount of gas accompanying the water is also strong evidence of the source of the uncommon pressure. It is also the belief of the writers that the flow will gradually decrease as the gas pressure is relieved, as would be expected in a sealed reservoir, and that in time it will entirely cease. The underground conditions causing this flow are a menace to the oil possibilities only of that territory which is underlain by the particular sand lens carrying the water. At present the southwestern limit of the lens is marked by a line running in a north-northwesterly direction between Northern wells Nos. 1 and 4. The extent of the lens toward the north, east, and south is problematical, although from some evidence the writers are led to believe that the unfavorable conditions extend northeastward for at least one-half mile from the southwestern limit of the lens.

Product.—The wells yield oil and sand, the latter sometimes making up nearly half the product. The oil is black and varies in gravity from 12° to 15° Baumé. Oil of 16° and 18° Baumé gravity is said to come from the shale and possibly certain sands toward the base of zone A. Much gas occurs with the oil and some of this is saved on most of the properties.

Production.—The production of the wells in this area varies from a mere trace, reported in one of the wells in the southwestern part, to an initial production of 800 barrels per day for one of the deeper holes. The average daily production after the initial head has blown off is between 100 and 250 barrels per well. The wells fall off materially in production with reduction of the gas pressure, but this deficiency is now being supplied on some of the properties by the installation of air compressors, which are used instead of pumps.

Methods.—The wells in this area are from 800 to over 1,200 feet deep. The water is shut off in the clay between the lowest water sand and the uppermost tar sand in zone A, that is, about 250 feet above the top of zone B. The second string of casing is usually landed in the clay above zone B. Clay rather than shell is utilized in this field for landing the casing, and is found very satisfactory as a general rule. The wells are operated, as in other parts of the field, by agitating the sand with the inner string of casing.

Typical log.—A typical log of the wells of this area is as follows:

Log of well near center of north line of sec. 12, T. 11 N., R. 24 W.

	Feet.
Surface	178
Blue clay	205
Water sand	206
Blue clay	220
Yellow clay and gravel	335
Blue clay	363
Hard shell	368
Blue clay	394
Shell	396
Blue clay	405
Shell	408
Blue clay	416
Clay and sand	468
Shell	469
Clay and sand	495
Shell	497
Water and sand	500
Blue shale	568
Shell	571
Blue clay	581
Sand, clay, and shell	590
Blue clay	593
Shell	624
Blue clay	638
Shell	640
Clay and sand	655
Blue clay	670
Water sand	675
Shell	677
Blue clay	685
Sand	690
Blue clay	696
Shell	700
Blue clay	760
Sand and clay (water)	785
Shell	788
Hard sand	796
Water	798
Shell	799
Blue clay	807
Tar sand	840
Blue clay	859
Shell	863
Oil sand	869
Shell	872
Blue clay	880
Oil sand	890
Blue clay	900
Shell	901
Oil sand	905

	Feet.
Shell	908
Blue clay	912
Shell	913
Gravelly clay	949
Oil sand	965
Good oil sand	980
Blue clay	985
Oil sand	990
Blue clay	1,002
Shell	1,003
Shale and gas	1,036
Shell	1,037
Gray shale	1,062
Blue clay	1,068
Hard shell	1,072
Blue shale	1,080
Shell	1,087
Oil sand	1,227

GOLDEN WEST—TOPAZ—NAVAJO AREA.

Location.—This area embraces the developed territory between the Golden West lease on the northwest (in the SE. ¼ sec. 12, T. 11 N., R. 24 W.) and the Navajo wells (in the NW. ¼ sec. 20, T. 11 N., R. 23 W.), and includes property operated by the Golden West, Lion, Topaz, Sunset Monarch (formerly American Girl lease), and Union oil companies. The area lies just at the bend of the strata from a southeasterly to an easterly strike, in a structural depression analogous to a plunging syncline.

Zone B.—In the northern part of the area zone B is not over 15 feet thick in the wells; in the middle portion of the area it is 15 to 32 feet thick; and at the east end of the area it is 15 to 40 feet, although a total of 130 feet of oil-bearing strata, much of which is shale, is reported in this part of the field. In one well in the east end of the area the upper 6 feet of the productive sand is soft and yields a showing of oil, while the lower 9 feet is hard and yielded oil in commercial quantities. Near the northeast corner of sec. 13 two sands, separated by 80 feet of clay, occur in the wells. The upper sand is about 20 feet thick, is medium-grained, and carries gas and oil in commercial quantities; the lower sand is thinner and yields heavy oil and tar. A dark-colored shale in the top of zone B or immediately above it yields oil in some of the wells in the north end of the area. The product is called "shale oil" by the operators. This horizon is probably the one yielding oil of 16° to 18° Baumé in wells to the north.

Zone A.—Zone A usually extends to about 220 feet above the top of zone B, and contains several sands 5 to 20 feet thick intercalated with greater thicknesses of shale and clay. A parting of 60 feet of shale or clay, with a hard shell at the base, separates zones A and B. The petroliferous layers vary from medium coarse sand to gravelly layers and some beds carrying cobbles of considerable size. Gas, oil, and tar are contained in the sands of zone A, the oil usually occurring in the lower sands and gas in the upper, although gas occurs in all of the petroliferous layers in greater or less quantities. Sulphur water is occasionally associated with the tar sands in the upper part of the zone.

Beds above zone A.—Blue clay with intercalated layers of sand, water sand, cobbles, and hard shell overlies zone A. The cobbles are more abundant in the southern part of the area than in the northern and central.

Water sands.—The abundance and productivity of the water sands are the most important characteristics of this area. This is to be expected where the wells penetrate a syncline, for, according to the well-known law of underground waters, they seek the lowest positions in the strata—that is, the bottoms of synclines. The zone of the water sands usually begins at about 120 feet below the surface, and from six to eight layers or lenses are encountered down to the top of zone A, from which the lowest water sand is separated by 15 to 60 feet of clay. The upper part of zone A also contains water in a few of the wells. The water sands are each from 5 to 40 feet thick and vary in composition from coarse sand to gravel carrying cobbles. The water is highly mineralized, much of it containing appreciable quantities of sulphur.

Water also occurs immediately below zone B in some parts of the area, especially near the axis of the syncline formed by the northeast and north-dipping beds. Such a condition calls for care in the operation of the wells in the affected territory, for too deep drilling is almost sure to result in a flooding of the productive sands by this "bottom water." Not only immediately below zone B, but still deeper, water occurs in sands interbedded with the shale. One well in the western part of the SW. ¼ sec. 18, T. 11 N., R. 23 W., struck hot sulphur water at a depth of about 1,700 feet.

Product.—The product of the various wells in this area ranges from tar just soft enough to flow to black oil of 16° to 17° Baumé gravity. The average for the shallow wells is about 11° to 12° Baumé; for the deeper ones about 15° or above. The heavy tar occurs in the shallow wells near the outcrop of the oil sands, the quality of the oil improving rapidly as the strata are tapped at greater and greater depths. Gas accompanies the oil in all the wells, but the pressure is not as great as in the areas to the north.

Production.—The production of most of the wells is light, usually under 25 barrels per day per well. Some of the deeper ones are said to promise 50 barrels when properly tested. This low production is also a feature that is to be expected in wells penetrating the trough of a syncline, if the conditions postulated for the anticlinal theory prevail in the area. Very little sand, as compared with the areas to the north, occurs in the oil in this territory.

Methods.—The wells in this area vary in depth from 10 or 12 feet in the area of dug wells in the asphalt outcrops to over 1,800 feet in the deeper territory. Water is usually shut off in the wells just above zone B. The oil is obtained by pumping and even by bailing in the dug wells. The gas pressure being low, the sand is not as troublesome as in wells where the pressure is great enough to cause the wells to flow.

Typical logs.—The following log is characteristic of the northwestern part of the area:

Log of well in central part of the S. ½ sec. 12, T. 11 N., R. 24 W.

	Feet.
Surface formation, hard gray sand with a little water	180
Shale and hard sand with increase of water	242
Brown sandstone	262
Hard shell	264
Soft gray sand	282
Black shale	292
Gray sand with increase of water	322
Blue sandy mud	367
Reddish-brown clay	380
Gray sandy mud, hard, odor of sulphur	395
Gray sandy clay, softer, little water	525
Black shale	535
Gray sand	660
Brown sandy shale	680

A typical log of the central part of the area, showing in addition to the oil sands the formation under them, is as follows:

Log of well in northwestern corner of SW. ¼ sec. 18, T. 11 N., R. 23 W.

	Feet.
Surface formation, alternating shale, yellow clay, sand, and brown shale	445
Blue shale	460
Yellow formation, water	480
Blue and yellow clay	567
Yellow water sand	573
Yellow clay	581
Blue clay	601
Blue water sand	612
Blue soft sand	621
Sticky blue clay	645
Blue water sand	654
Blue sandstone	670
Sticky blue clay	730
Fine loose sand (sulphur)	734
Stiff blue clay	740
Blue sand (much water), little gas and oil	748

	Feet.
Soft blue clay	756
Blue clay with gravel	760
Hard shell	761
Fine sand and clay	766
Coarse gravel	768
Blue clay	782
Tar sand, little gas	788
Blue clay, soft	800
Hard shell	801
Tar sand	803
Hard shell	807
Tar sand	809
Blue formation clay	835
Brown sand, coarse gravel, with oil	843
Hard shell	847
Brown sandstone with pockets of gas and oil	851
Tar sand and cobbles	861
Blue clay	871
Hard shell	872
Blue clay	960
Blue clay and gravel	962
Hard shell (drilled slow)	965
Brown sandstone, soft	986
Hard shell	989
Brown shale	994
Gray sand with water and gas	1,052
Brown shale	1,054
Brown shale with water	1,135
Reddish-brown shale (more gas)	1,144
Brown shale (caving)	1,384
Brown shale	1,292
Brown shale with thin strata of fine sand	1,330
Brown shale, harder	1,370
Brown shale with streaks of water	1,396
Hard sandy shell	1,401
Soft brown shale with a little water	1,413
Brown shale	1,537
Brown shale, softer	1,561
Gray sand with water	1,580
Gray sandy shale	1,595
Hard shell	1,597
Brown shale	1,671
Brown shale with fine sand and water	1,716
Brown shale	1,728
Hard shell	1,736
Hot sulphur water	1,750
Brown shale	1,785
Gray sand	1,797

DEVELOPED AREA SOUTHEAST OF SUNSET.

Location.—This area embraces the region for about 2 miles southeast of the Navajo wells and includes secs. 17, 20, 21, and 28, T. 11 N., R. 23 W. The territory has been affected by a number of profound faults, which have, among other results, brought the petroliferous diatomaceous shales up to the surface in the northern parts of secs. 20 and 21, where one would expect to find the McKittrick formation if the strike of the beds were constant eastward from the Navajo wells. It is from these siliceous shales that the wells in what are termed "group 2" in the following notes derive their oil. Unfortunately, much of the region under discussion is covered by alluvial and stream deposits of recent origin, so that it is impossible to discover the relations between these shale areas (represented as asphalt on the map, Pl. I) and the adjacent younger beds.

Description of developments.—At the time of the writers' visit to this area all the wells were abandoned. The shallow ones which were put down in the asphalt-impregnated shales had seeped full of heavy tar; the deeper ones were either clogged with débris or contained water. The following description of the developments in this area is by W. L. Watts,[a] who visited this region in 1893:

Messrs. Jewett and Blodgett bored two groups of wells in the mesa lands of the Sunset Oil district. One of these groups, "group 1," is in the NW. ¼ sec. 21; and the other, "group 2," is in the NE. ¼ sec. 28. In group 1 there are 13 wells, 1 of these being 1,300 feet in depth, the remainder varying from 80 to 500 feet in depth. The 1,300-foot well yielded flowing water and much gas; the others yield a heavy oil by pumping. The 12 oil-producing wells are all situated within an area of about 400 feet in length and 30 feet in width. The 1,300-foot well was bored a short distance in a northeasterly direction from the most northerly of the oil-yielding wells. The 12 oil wells yield altogether about 15 barrels of oil every twenty-four hours. The specific gravity of this oil varies in the different wells from about 12° Baumé to a heavy liquid asphaltum that requires to be heated by steam, which is forced to the bottom of the well before the heavy oil can be pumped. Six of these are dry wells, and are sunk to a depth of from 80 to 100 feet. The stratum yielding the greater portion of the heavy oil is about 35 feet in thickness. The other 6 are drilled wells, varying from 150 to 500 feet in depth. All of these wells are sunk to a sufficient depth to form reservoirs at the bottom capable of storing the oil which gathers during several days, for a few hours of pumping is sufficient to pump the oil accumulated during twenty-four hours.

The following records show the character of the formation penetrated by the wells belonging to group 1:

Well No. 1.

Bored in March, 1891. This well was commenced with 11-inch casing.

	Feet.
Surface drift	50
Light-colored shale	400
At this depth mineral water rose to within 40 feet of the top of the casing.	
Black sandy shale	559
At this depth the diameter of casing was reduced to 8⅝ inches.	

[a] Bull. California State Min. Bur. No. 3, 1894, pp. 27 et seq.

	Feet.
Black sandy shale with black sulphur water	610
At this depth casing reduced to 6⅝ inches.	
Black sandy shale	700
Gas from this depth burned with a flame 4 feet high from a 7-inch pipe.	
Black sandy shale, with oil in seams	900
At this depth casing reduced to 5⅝ inches.	
Very light-colored shale, to a depth of	928
Gray sand rock, with flowing water, to a depth of	995
At this depth the well flowed 50 barrels of mineral water daily and yielded much gas but little oil.	
Light-colored shale, to a depth of	1,235
Dark-colored shale, which caved badly, to a depth of	1,250
At this depth casing reduced to 4¼ inches.	
Dark-colored shale, to a depth of	1,290

The first gas was noticed at a depth of 600 feet, and two other distinct flows were struck at depths of 928 and 1,200 feet, respectively.

Well No. 4.

	Feet.
Asphaltum	50
Drift from the mountain	65
Shale, with some oil	70
Dark-colored shale and oil	130
Dark-colored shale, without oil	160
Light-colored shale	237

About 40 or 50 barrels of mineral water flowed from this well daily.

Well No. 6.

	Feet.
Wash and drift	30
Dark shale and oil	75
Dark shale, without oil	120

The boring ended in light shale. There was no water in this well.

In 1892–93 Messrs. Jewett and Blodgett bored three wells on the mesa lands in sec. 28, at a point a little more than a mile distant from group 1 and in a southeasterly direction therefrom. The following record shows the character of the formation penetrated:

Well No. 3.

This well is situated about 150 paces a little east of south from well No. 2.

	Feet.
For the first 300 feet a similar formation was penetrated to that passed through in wells Nos. 1 and 2	300
Bluish gray sandstone, with an occasional streak of darker-colored and sharper sand	755
At this depth there was much gas and a little oil. At the depth of 540 feet the water was shut off with 6⅝-inch casing.	
Brown sand, with considerable oil	815
Barren sandstone	940
Oil-bearing sandstone	950
Light-blue sand	1,030
At this depth a blue clay impeded drilling.	
Dark-blue sandstone, with more gas	1,060
Light-blue sandstone, with more gas	1,180
At this depth there was an increase in the amount of gas and oil.	

	Feet.
Sandstone	1,210
Black shale	1,215
Sandstone	1,220
Close-grained shale, with more oil	1,270
Oil sand	1,295
Coarse sand	1,350

It is the gas from this well which was used in the experiments on the fuel value of the gas at Sunset.

The oil yielded by the oil wells of group 2 is a dark-green oil and possesses a lower specific gravity than that yielded by the oil wells of group 1.

The Nevada Pacific Oil Company has just drilled a well in the SW. ¼ SW. ¼ sec. 24, T. 11 N., R. 23 W., in which a heavy tar was encountered in a coarse clean sand at about 500 feet below the surface. This well is the farthest east in the district that has encountered tar or oil.

OIL COMPANIES AND OIL WELLS IN SUNSET DISTRICT.

In the following list of companies and wells the locations refer to the San Bernardino base and meridian.

Oil companies and oil wells in the Sunset district.

Name of oil company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Adeline		1	SE. ¼ sec. 2, T. 11 N., R. 24 W	830
Do		2	do	830
Do		3	do	830
Do		4	do	
Do		5	do	830
Do		6	do	830
Do		7	do	830
Do		12	do	
Do		13	do	837
Do		24	do	840
Do		25	do	845
Do	Superior	1	SE. ¼ sec. 2, T. 11 N., R. 24 W	840
Do	do	2	do	830
Do	do	3	do	840
Alpha (*see* Union)	Alameda			
Arcola	do	1	SW. ¼ sec. 2, T. 11 N., R. 24 W	975
Do		2	do	950
Do. (water well)			do	975
Do	Euclid	1	SW. ¼ sec. 2, T. 11 N., R. 24 W	975
Arcola Extension	Dirigo	1	SE. ¼ sec. 2, T. 11 N., R. 24 W	850
Do	do	2	do	830
Barrett. (*See* Union.)				
Bronco		1	NW. ¼ sec. 8, T. 11 N., R. 23 W	
Beaver		1	N. ½ sec. 34, T. 12 N., R. 24 W	936
Do		2	do	970
Do		3	do	992
California Diamond	Obispo	1	NW. ¼ sec. 2, T. 11 N., R. 24 W	995
Do		2	do	1,000
Do		3	do	980
California Fortune. (*See* Tannehill.)				
California King	Yellowstone	1	NE. ¼ sec. 7, T. 11 N., R. 23 W	
Catfish. (*See* Union.)				
Charter. (*See* Union.)				
Chicago Guarantee. (*See* Union.)				
Conservative	Lion	1	SE. ¼ sec. 12, T. 11 N., R. 24 W	830
Do	do	2	do	825
Colorado and California Fuel. (*See* Union.)				
Dahlia. (*See* Union.)				
Dirigio. (*See* Arcola Ext.)				
Dunn & Barrett	Wiethase	1	SE. ¼ sec. 8, T. 11 N., R. 23 W	
El Rey		1	NE. ¼ sec. 2, T. 11 N., R. 24 W	890±
Essex		1	NE. ¼ sec. 6, T. 11 N., R. 23 W	
Ethel D	R. E. Graham	1	SE. ¼ sec. 36, T. 12 N., R. 24 W	

Oil companies and oil wells in the Sunset district—Continued.

Name of oil company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Ethel D	R. E. Graham	2	SE. ¼ sec. 36, T. 12 N., R. 24 W.	
Euclid. (*See* Arcola.)				
Federal Crude. (*See* Union.)				
Fulton		1	SW. ¼ sec. 1, T. 11 N., R. 24 W.	835
Do		2	do	838
Do		3	do	832
Do		4	do	842
Do		5	do	829
Do		6	do	847
Do		7	do	803
Do		8	do	810
Do. (water well)			do	840
Do		9	do	
Do		10	do	
Do		11	do	
Gate City		1	SW. ¼ sec. 1, T. 11 N., R. 24 W.	850
Do		2	do	840
Do		3	do	838
Do	Maricopa	1	SW. ¼ sec. 1, T. 11 N., R. 24 W.	850
Do	do	2	do	839
Do	do	3	do	847
Do	do	4	do	840
Do	do	5	do	847
Do	do	6	do	
Do	do	7	do	
Do	do	8	do	
Do	do	9	do	
Do	do	10	do	
Golden Gate. (*See* Union.)				
Golden West		1	SE. ¼ sec. 12, T. 11 N., R. 24 W.	783
Do		2	do	
Graham & Sinter	Wiethase	1	SW. ¼ sec. 8, T. 11 N., R. 23 W.	
Do	do	2	do	
Graham, Frank		1	SE. ¼ sec. 10, T. 11 N., R. 23 W.	
Do		1	SW. ¼ sec. 12, T. 11 N., R 23 W.	
Do		1	SW. ¼ sec. 14, T. 11 N., R. 23 W.	
Do		1	SW. ¼ sec. 15, T. 11 N., R. 23 W.	
Hanford Sanger. (*See* Monarch Eagle.)				
Do		2	do	995
Hazelton Crude		1	SW. ¼ sec. 17, T. 11 N., R. 23 W.	
Hazelton Water. (*See* Union.)				
Hill Well. (*See* Union.)				
J. B. & B. (*See* Union.)				
Jewett & Blodgett. (*See* Union.)				
Johnson	Graham & Sinter	1	NE. ¼ sec. 8, T. 11 N., R. 23 W.	
Do	do	2	do	
Do	do	3	do	
Do	"400"	1	SE. ¼ sec. 7, T. 11 N., R. 23 W.	675
K. T. & O	C. E. Graham	1	NE. ¼ sec. 1, T. 11 N., R. 24 W.	
Do	do	2	do	
Do	do	3	do	
Do	do	28	do	
La Blanc	Sunset Ext.	1	NW ¼ sec. 6, T. 11 N., R. 23 W.	
Lady Washington No. 1	Haviland	1	SW. ¼ sec. 6, T. 11 N., R. 23 W.	718
Lady Washington No. 2	Yellowstone	2	NW. ¼ sec. 7, T. 11 N., R. 23 W.	684
Lion. (*See* Conservative.)				
Loma Vista	Kern Sunset	1	NE. ¼ sec. 12, T. 11 N., R. 24 W.	810
Do	do	2	do	810
Do	do	3	do	
Do	do	4	do	
Maricopa-McKittrick Cons'd.		1	NW. ¼ sec. 36, T. 12 N., R. 24 W.	
Do		2	do	
Main Line		1	SE. ¼ sec. 6, T. 11 N., R. 23 W.	
Manitoba	Yellowstone	1	NE. ¼ sec. 7, T. 11 N., R. 23 W.	
McCutcheon	Petroleum Center	1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	818
Do	do	2	do	812
Do	do	3	do	
Do		1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	820
Do		2	do	830
Do		3	do	818
Do		4	do	815
Do		5	do	
Do		6	do	
Mohawk-Sunset		1	SE. ¼ sec. 1, T. 11 N., R. 24 W.	
Monarch Eagle	Hanford-Sanger	1	NE. ¼ sec. 3, T. 11 N., R. 24 W.	990
Do	do	2	do	995
Do	do	3	do	
Monte Cristo	Pittsburg	1	NW. ¼ sec. 1, T. 11 N., R. 24 W.	795
Do		2	do	788

Oil companies and oil wells in the Sunset district—Continued.

Name of oil company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Monte Cristo		3	NW. ¼ sec. 1, T. 11 N., R. 24 W.	804
Do		4	do	780
Do		5	do	800
Do		6	do	781
Do		7	do	817
Do		8	do	779
Do		9	do	826
Do		10	do	773
Do		11	do	832
Do		12	do	776
Do		13	do	840
Do		14	do	
Do		15	do	838
Do		16	do	
Do		32	do	
Munzer		1	NW. ¼ sec. 7, T. 11 N., R. 23 W.	
Muscatine		1	SE. ¼ sec. 1, T. 11 N., R. 24 W.	
Do		2	do	
Do		3	do	
Nanticoke. (*See* Union.)				
Nevada Pacific		1	SW. ¼ sec. 24, T. 11 N., R. 23 W.	
New Center		1	NW. ¼ sec. 12, T. 11 N., R. 24 W.	830
Do		2	do	805
Do		3	do	806
Do		4	do	816
Do		5	do	808
Do		6	do	805
Do		7	do	815
Do		8	do	820?
Do		9	do	
Do		10	do	820?
Northern		1	NE. ¼ sec. 12, T. 11 N., R. 24 W.	755
Do		4	do	760
Obispo		1	SW. ¼ sec. 32, T. 12 N., R. 23 W.	
Occidental	Sunset Monarch	A	SW. ¼ sec. 7, T. 11 N., R. 23 W.	760
Do	do	B	do	765
Do	do	C	do	770
Do	do	D	do	
Occidental. (*See* Sunset Monarch.)				
Pacific. (*See* Phoenix Refining.)				
Petroleum Center. (*See* McCutcheon.)				
Phoenix Refining. (*See* Union.)				
Pittsburg. (*See* Monte Cristo.)				
Queen (*See* Union.)				
Ruby		1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	825
Do		2	do	817
Do		3	do	838
Do		4	do	810
Do		5	do	
Do		6	do	
Do		7	do	
Do		8	do	
Sage. (*See* Union.)				
Santa Rosa. (*See* Sunset Monarch.)				
Sedalia-California. (*See* Union.)				
Snook, Walter	Tiger	1	NE. ¼ sec. 12, T. 11 N., R. 24 W.	804
Do		2	do	808
Do		3	do	801
Do		4	do	804
Stone. (*See* Union.)				
Sunset Acme	Reynolds (Acme)	1	SE. ¼ sec. 34, T. 12 N., R. 24 W.	1,025
Do	do	2	do	1,009
Do	do	3	do	1,020
Do	do	4	do	1,010
Sunset Diamond. (*See* Union.)				
Sunset Monarch. (*See* Occidental.)	American Girl No. 1.			
Sunset Monarch	Occidental	1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	940
Do	do	2	do	935
Do	do	3	do	925
Do	do	4	do	935
Do	do	5	do	
Do	Santa Rosa	1	NW. ¼ sec. 2, T. 11 N., R. 24 W.	1,000
Do	do	2	do	1,020
Do	do	3	do	1,030

Oil companies and oil wells in the Sunset district—Continued.

Name of oil company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Sunset Monarch	Sunset Monarch	1	NW. ¼ sec. 2, T. 11 N., R. 24 W.	980
Do	do	2	do	975
Do	do	3	do	945
Do	do	4	do	940
Do	do	5	do	930
Do	do	6	do	940
Do	do	7	do	925
Do	do	8	do	842-942(?)
Do	do	9	do	890-900(?)
Do	do	10	do	850-890(?)
Do		A	SW. ¼ sec. 26, T. 12 N., R. 24 W.	876
Do		B	do	840
Do		C	do	900
Do	Transport	1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	830
Do	do	2	do	825
Do	do	3	do	820
Do	do	4	do	820
Do	do	5	do	830
Do	do	6	do	830
Do	do	7	do	
Do	Tremont	1	NW. ¼ sec. 2, T. 11 N., R. 24 W.	900
Do	do	2	do	920
Do	do	3	do	890
Sunset Petroleum and Refining.		1	NE ¼ sec. 29, T. 11 N., R. 23 W.	
Sunset Queen		1	NW. ¼ sec. 14, T. 11 N., R. 24 W.	1,090
Sunset Rex		1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	840
Do		2	do	842
Do		3	do	
Sunset Road. (*See* Union.)				
Superior. (*See* Adeline.)				
Tannehill	California Fortune.	1	NW. ¼ sec. 34, T. 12 N., R. 24 W.	1,120
Do	do	2	do	1,125
Do	do	3	do	1,120
Do	do	4	do	1,140
Do	do	5	do	1,150
Do	do	6	do	1,160
Do	do	7	do	1,120
Do		8	do	
Do		9	do	
Teck		1	NE. ¼ sec. 3, T. 11 N., R. 24 W.	990
Do		2	do	1,035
Do		3	do	980
Do		4	do	
Tiger. (*See* Snook, Walter.)				
Topaz		1	SE. ¼ sec. 12, T. 11 N., R. 24 W.	755
Do		2	do	724
Union	Alpha	(?) 1	NW. ¼ sec. 13, T. 11 N., R. 24 W.	800
Do	do	(?) 2	do	795
Do	do	3	do	780
Do	do	4	do	780
Do	do	5	do	780
Do	do	6	do	780
Do	do	8	do	780
Do	Barrett	1	SE. ¼ sec. 2, T. 11 N., R. 24 W.	850
Do	do	2	do	850
Do	Catfish	1	NE. ¼ sec. 33, T. 12 N., R. 24 W.	1,165
Do	do	2	do	1,230
Do	Charter	1	NE ¼ sec. 13, T. 11 N., R. 24 W.	785
Do	Chicago Guarantee	1	W. ½ sec. 18, T. 11 N., R. 23 W.	790
Do	do	2	do	820
Do	Colorado and California Fuel.	1	NW. ¼ sec. 35, T. 12 N., R. 24 W.	1,018
Do	do	2	do	1,034
Do	do	1	S. ½ sec. 12, T. 11 N., R. 24 W.	835
Do	do	2	do	830
Do	do	3	do	
Do	do	4	do	
Do	Crown	1	NE. ¼ sec. 13, T. 11 N., R. 24 W.	
Do	Dahlia	1	SE. ¼ sec. 35, T. 12 N., R. 24 W.	900±
Do	Federal Crude	1	NW. ¼ sec. 35, T. 12 N., R. 24 W.	1,018
Do	do	2	do	1,034
Do	Golden Gate	1	NE. ¼ sec. 34, T. 12 N., R. 24 W.	953
Do	Hazelton Water	1	NW. ¼ sec. 13, T. 11 N., R. 24 W.	
Do	do	2	do	800±
Do	Hill	1	SW. ¼ sec. 18, T. 11 N., R. 23 W.	775
Do	J. B. & B. (Sunset Road).	1	SW. ¼ sec. 35, T. 12 N., R. 24 W.	957
Do	do	2	do	952
Do	do	3	do	958
Do	do	4	do	929
Do	do	5	do	923

Oil companies and oil wells in the Sunset district—Continued.

Name of oil company.	Former name.	No. of well.	Locality.	Elevation.
				Feet.
Union	J. B. & B. (Sunset Road).	6	SW. ¼ sec. 35, T. 12 N., R. 24 W.	960
Do	do	7	do	939
Do	do	8	do	955
Do	do	9	do	977
Do	do	10	do	981
Do	do	11	do	964
Do	do	12	do	999
Do	do	1	NW. ¼ SW. ¼ sec. 35, T. 12 N., R. 24 W.	961
Do	J. B. & B. (Navajo)	1	NW. ¼ sec. 20, T. 11 N., R. 23 W.	
Do	do	2	do	
Do	do	3	do	
Do	do	1	SW. ¼ sec. 11, T. 11 N., R. 24 W.	
Do	do	1	SE. ¼ sec. 34, T. 12 N., R. 24 W.	
Do	J. B. & B. (Czar)	1	N. ½ sec. 19, T. 11 N., R. 23 W.	
Do	J. B. & B. (Sunset King).	2		
Do	Jewett & Blodgett.	17	SW. ¼ sec. 18, T. 11 N., R. 23 W.	820
Do	Nanticoke	1	SE. ¼ sec. 27, T. 12 N., R. 24 W.	900+
Do	Phœnix (Pacific)	1	SW. ¼ sec. 35, T. 12 N., R. 24 W.	945
Do	do	2	do	936
Do	Queen	1	NW. ¼ sec. 14, T. 11 N., R. 24 W.	775
Do	Sage	1	E. ½ sec. 35, T. 12 N., R. 24 W.	794
Do	do	2	do	792
Do	do	3	do	774
Do	do	4	do	748
Do	do	5	do	825
Do	do	6	do	825
Do	do	7	do	
Do	do	8	do	
Do	do	9	do	
Do	do	10	do	
Do	Sedalia-California	1	W. ½ sec. 18, T. 11 N., R. 23 W.	775
Do		2	do	770
Do		3	do	765
Do		4	do	760
Do		5	do	765
Do		6	do	750
Do		7	do	750
Do		8	do	
Do		9	do	
Do		10	do	
Do	Stone	1	SE. ¼ sec. 28, T. 12 N., R. 24 W.	1,240
Do	Sunset Diamond	1	NE. ¼ sec. 13, T. 11 N., R. 24 W.	775
Do	do	2	do	775
Do	do	3	do	
Do	Webster	1	SE. ¼ sec. 35, T. 12 N., R. 24 W.	796
Do	do	2	do	892
Do	do	3	do	907-923(?)
Do	do	4	do	832
Do	do	5	do	795
Do	do	6	do	782
Do	do	7	do	830
Do	do	8	do	
Do	do	9	NW. ¼ sec. 35, T. 12 N., R. 24 W.	800
Do	Wichita	1	SE. ¼ sec. 2, T. 11 N., R. 24 W.	850
Do	do	2	do	850
Do	do	3	do	
Do	do	4	do	
United Crude		1	NE. ¼ sec. 2, T. 11 N., R. 24 W.	825
Do		2	do	830
Do		3	do	820
Do		4	do	818
Do		5	do	816
Do		6	do	814
Wellman	R. E. Graham	1	SW. ¼ sec. 36, T. 12 N., R. 24 W.	
Do	do	2	do	
Do	do	3	do	788
Do	do	4	do	779
Do	do	5	do	773
Do	do	6	do	
Western Minerals		1	N. ½ sec. 17, T. 11 N., R. 23 W.	
Do		2	do	
Do		1	SW. ¼ sec. 17, T. 11 N., R. 23 W.	910
Do		2	do	905
Do		1	Sec. 12, T. 11 N., R. 23 W.	
Do		1	N. ½ sec. 22, T. 11 N., R. 23 W.	
Do		1	SW. ¼ sec. 23, T. 11 N., R. 23 W.	
Do		1	N. ½ sec. 25, T. 11 N., R. 23 W.	
Do		1	SW. ¼ sec. 26, T. 11 N., R. 23 W.	
Wichita. (*See* Union.)				

DEVILS DEN FIELD.

LOCATION.

The territory in which drilling operations have been carried on in the Devils Den district includes the central-eastern part of T. 25 S., R. 17 E., and secs. 22, 23, and 24, T. 25 S., R. 18 E. Among the operating companies have been the Spreckles Oil Company, the Devils Den Oil Company, and the Pluto Oil Company. (See list, p. 199.)

GEOLOGY.

The oil-bearing formation of the Devils Den district, as indicated by the tar springs in sec. 25, T. 25 S., R. 18 E., and by the well logs, is the Vaqueros sandstone or the sand lenses interbedded at the base of the shale of the Santa Margarita (?) formation. The Spreckles wells put down several years ago in the eastern part of sec. 24, T. 25 S., R. 17 E., and in the western part of sec. 30, T. 25 S., R. 18 E., penetrated the Cretaceous rocks (Knoxville-Chico) but obtained no petroleum. The logs of but two wells were available in the study of this district. They are given below and indicate that the oil zone is overlain by white and brown shales, in which are hard yellow concretionary layers. The sand itself is quite hard and rather coarse-grained, consisting largely of quartz. The oil-bearing beds occur as a monocline passing in a northwest-southeast direction through secs. 11, 13, 14, and 24, with a somewhat similar monocline passing in an east-west direction through secs. 22, 23, and 24. The first monocline becomes the northeastern flank of an anticline in sec. 14, and this anticline passes into the monocline of secs. 22 and 23.

PRODUCT AND PRODUCTION.

The products of the wells are of two qualities. The sands intercalated with the shales produce an oil said to have a gravity of about 23° Baumé, while the underlying coarser sand of the Vaqueros yielded much heavier oil or tar. Neither well has been properly tested for production, but the one producing the light oil was estimated to be capable of yielding about 10 barrels per day.

It is stated that a thick oil has been struck at a depth of 400 feet by the Pluto Oil Company, in the NW. ¼ sec. 19, T. 25 S., R.19 E.

WELL LOGS.

The following logs of the two wells which had been drilled in the district previous to the visit of the writers in the summer of 1908 were kindly furnished by Prof. O. D. Barton, of Dudley:

Log of Devils Den Oil Company well No. 1, in the NE. ¼ sec. 23, T. 25 S., R. 18 E., Devils Den district (drilled in 1901).

	Feet.
First water	45
Second water, rose within 15 feet of surface	78
Top of reef (Vaqueros)	426
Reef proper, hard, carries heavy oil	427–431
Oil sand, oil heavy, stuck to tools, lighter than that above	431–446
Hard reef	446–460
Sand carrying water like tar spring	460–636
Light-colored shale	636–780

Log of Niagara Oil Company well No. 1, in NW. ¼ sec. 22, T. 25 S., R. 18 E., Devils Den district.

	Feet.
White shale	100
Yellow shale, hard	104
White shale	304
Dark brown shale	329
Hard silicified shale	332
Oil sand (estimated 23° Baumé gravity, carried oil all the way, estimated at 10 barrels per day)	372
Sand with water	600
Reef of hard sandstone	603
Water sand	703
Hard sand, limy	709
Streak of good water	960
Blue shale (drilling)	1,145

OIL COMPANIES AND OIL WELLS.

The following list of the oil companies operating in the Devils Den district, with the location of their wells, has been corrected up to December 25, 1909, by Mr. Guy H. Salisbury.

Oil companies and oil wells in Devils Den district.

Name of oil company.	Number of wells or rigs.	Locality.
Colt	1 well	SW. ¼ sec. 5, T. 25 S., R. 19 E.
Cosmos	do	SE. ¼ sec. 31, T. 25 S., R. 19 E.
Devils Den Consolidated	2 wells	NW. ¼ sec. 22, T. 25 S., R. 18 E.
Dominion		S. ½ S. ½ sec. 7, T. 23 S., R. 17 E.
Dougherty & Johanson	1 well	Sec. 2, T. 26 S., R. 19 E.
East Oakland	do	NW. ¼ sec. 2, T. 26 S., R. 18 E.
Etzenhause	do	Sec. 27, T. 24 S., R. 18 E.
Gibraltar (operating company)	1 rig	SW. ¼ sec. 5, T. 24 S., R. 18 E.
Greasy Jim	1 well	SE. ¼ sec. 9, T. 25 S., R. 18 E.
Do		S. ½ sec. 15, T. 25 S., R. 18 E.
Kerns & Berry	1 well	SE. ¼ sec. 26, T. 25 S., R. 19 E.
Lindsay (Incorporated)	do	SW. ¼ sec. 9, T. 25 S., R. 18 E.
Lovelace & Rarr	do	NE. ¼ sec. 27, T. 25 S., R. 19 E.
Do		SW. ¼ sec. 26, T. 25 S., R. 19 E.
Marathon	1 well	NE. ¼ sec. 13, T. 25 S., R. 18 E.
Pluto	do	NW. ¼ sec. 19, T. 25 S., R. 19 E.
Positive	1 rig	NE. ¼ sec. 31, T. 25 S., R. 19 E.
Swastika (holding company)		S. ½ sec. 5, T. 24 S., R. 18 E.
Tres Cerritos	1 well	SW. ¼ sec. 13, T. 25 S., R. 18 E.
Do	do	SW. ¼ sec. 15, T. 25 S., R. 18 E.
True Blue	do	Sec. 24, T. 25 S., R. 18 E.
Walker	1 rig	NW. ¼ sec. 29, T. 25 S., R. 19 E.
West Side Oil and Development.	1 well	SW. ¼ sec. 2, T. 25 S., R. 19 E.

TEMBLOR FIELD.

LOCATION.

The Temblor field occupies the low hills northwest of McKittrick as far as the Carneros Springs. It includes the northeastern part of sec. 29 S., R. 20 E., and the southeastern part of T. 29 S., R. 21 E. The companies which have drilled or are now operating in this district are, among others, the Associated, De Groot, Section Six (formerly Climax), and Springfield.

STRUCTURE.

The principal lines of structure affecting the territory under discussion are the Temblor anticline, and an anticline here called the "Gould," which passes from sec. 13, T. 29 S., R. 20 E., eastward to sec. 17, T. 29 S., R. 21 E., and thence in a southeasterly direction to the hills in front of Frazer Spring. The location of the axis of this last anticline across the Temblor Valley is hypothetical, as stream wash covers the area in question. Many local folds and faults complicate the structure. These are shown on the map and will not be described in detail. The Temblor anticline begins in sec. 26, T. 29 S., R. 20 E., and passes easterly to sec. 32, T. 29 S., R. 21 E., where it becomes somewhat sinuous. It is not possible to trace the axis continuously between the two sections mentioned, but the general geologic features of the region clearly indicate that the anticline exists as described, and suggests that faults are associated with it. The only productive wells so far encountered in the southern part of the field are along or near the axis of this anticline.

OIL SANDS.

The productive sand in the Temblor field is of Vaqueros (lower Miocene) age and in surface outcrops is about 200 to 400 feet in thickness. Tar springs and asphalt deposits mark the trace of this sand near the axis of the Temblor anticline in sec. 36, T. 29 S., R. 20 E.

OIL WELLS.

It is near the tar springs in sec. 36 that most of the productive wells of the field are drilled. These wells are from about 250 to more than 535 feet deep. The oil sand is encountered at depths ranging from a little more than 200 feet to about 400 feet, and is penetrated in the wells 24 to 100 feet. The sand is coarse and consists of quartz grains, and in places carries small pebbles of granite and metamorphic rock. Shale partings sometimes occur between the sand layers. These partings are thin and important in separating the oil from the water which is found in the oil zone.

Several other wells besides those mentioned as having been drilled on sec. 36 have been put down at various points along the Temblor anticline, in the shale area east of it. The logs of the wells put down in the shale indicate that the formation above the oil zone is, except for a few insignificant sand lenses, entirely shale. None of these wells is said to have yielded oil except the De Groot, near the center of the NW. ¼ sec. 32, T. 29 S., R. 21 E., and in this the occurrence of oil is more or less questionable. It is said that this well is more than 1,300 feet deep and penetrates the oil sand near the bottom.

Several wells which obtained no oil and were later abandoned were at one time drilled in the region north of the Temblor ranch. Among these is one in the northeast corner of the SW. ¼ sec. 24, T. 29 S., R. 20 E., which now contains water. Blue shale found on the sump adjacent to this well indicates the character of the beds penetrated by the drill. Although the well starts in the shale only a short distance above the reef bed, the strata here dip so deeply that the reef was never encountered in the well. Another abandoned well, in the SE. ¼ sec. 17, T. 29 S., R. 20 E., yields about one-half inch of salt water. This well is capped and produces a hissing sound as the water flows out, indicating a considerable gas pressure. No odor is perceptible in the vicinity, so it is unlikely that the gas contains much sulphur.

Several wells have been drilled on the north flank of the Gould anticline in sec. 12, T. 29 S., R. 20 E., and sec. 7, T. 29 S., R. 21 E. The wells in the last-mentioned section penetrate the diatomaceous shale of the Santa Margarita(?) and yield small quantities of oil. No data are available concerning the logs of these wells or the amount or quality of the oil produced, but conditions around the abandoned property indicate that the wells were shallow and the production not large. It is believed that the best production in this area will be obtained from a 20-foot stratum of oil sand at the base of the McKittrick formation overlying the diatomaceous shale just mentioned. The wells in sec. 12, T. 29 S., R. 20 E., penetrate the Miocene shale and are said to have attained a depth of nearly 2,000 feet, encountering 15 to 20 feet of oil sand near the bottom. It is believed that this sand lies near the base of the Monterey formation, and had the drills gone far enough below this they would probably have encountered the more productive sand at the top of the Vaqueros (lower Miocene).

PRODUCT AND PRODUCTION.

The product of those wells which have penetrated the oil-bearing beds consists of black oil varying in gravity from about 14° up to 20° Baumé. The production of the wells in sec. 36, T. 29 S., R. 20 E., varies from a few barrels to over 60 barrels a day. Large quantities of sulphur water accompany the oil from the wells. The occurrence of the water with the oil is probably accounted for by the failure of the drillers to shut off the water and by the fractured condition of the beds adjacent to the faulted anticline which passes near the wells. It is believed that wells which may penetrate the oil zone at a distance from the anticline in this locality will encounter more favorable conditions.

CARRIZO PLAIN FIELD.

LOCATION.

The region generally known as the "Carrizo Plain district" embraces Carrizo and Elkhorn plains and the adjacent southwestern flank of the Temblor Range. The supposed oil territory occupies the flanks of the hills toward the base of the range and the edge of the Carrizo and Elkhorn plains.

GEOLOGY.

The oil in the Carrizo Plain district occurs in sandstones interbedded with the base of the Monterey shale, or at the top of the Vaqueros, or in beds unconformably overlying the Monterey and Vaqueros. The Vaqueros sandstones are coarse and consist largely of quartz grains, with occasional granite and black to varicolored quartzite pebbles. The sandstone is roughly concretionary, the concretions sometimes attaining a diameter of 10 or 15 feet. The beds carrying oil, which unconformably overlie the Vaqueros and Monterey, consist of granitic débris and rounded shale fragments. The shallow wells, of which all the successful ones penetrate the base of the Monterey or the top of the Vaqueros, have in most instances been put down close to the axis of those anticlines which have an arched top and steep-dipping sides. There are several of these anticlines (shown on the map, Pl. I) which expose the Vaqueros sandstone or bring it close to the surface. Faults accompany most of the anticlines, and so complicate the structure that predictions concerning the territory a short distance away from the axis of an anticline are extremely hazardous.

An oil sand consisting of shale and other pebbles associated with granitic sand, and believed to be of later age than the Monterey, is exposed in the southern part of the area. A particularly advantageous place for studying this is about one-half mile west of the Vishnu well, in the southern part of sec. 22, T. 32 S., R. 22 E. The sand here is probably over 15 or 20 feet thick, and is overlain by fine-grained brown shales. This oil sand lies in a syncline, near the eastern edge of which the Vishnu well has been put down. It is believed that the Vishnu well obtains its oil from the Monterey or Vaqueros many hundreds of feet below the sand just described.

OIL WELLS.

No commercially productive wells have been drilled in the district, but several prospect wells have. Among these, beginning at the northwest, are the R. M. Smith well No. 1, in the northeast corner of sec. 21, T. 30 S., R. 20 E.; the seven wells of the R. M. Smith Oil Company, near the corner stake of secs. 22, 23, 26, and 27, T. 30 S., R. 20 E.; the Cree well, in the southwest corner of sec. 22, T. 31 S., R. 21 E.; the Erume test holes, in the southern part of the same section; the Schwartz well of the Union Company, near the southeast corner of sec. 6, T. 32 S., R. 22 E.; and the Sperry or Vishnu well, in the southeast corner of sec. 22, T. 32 S., R. 22 E.

The R. M. Smith wells in secs. 22, 23, 26, and 27, T. 30 S., R. 20 E., the Erume wells in sec. 22, T. 31 S., R. 21 E., and the Vishnu well, in sec. 22, T. 32 S., R. 22 E., have yielded traces of oil. The Smith and Erume wells are shallow and have yielded oil only in small quantities. The oil is of a good quality, and is said to test about 28° Baumé gravity, although occurring within less than 100 feet of the surface. It is brownish to greenish in color and has very little viscosity. It is said that this oil is used in its native condition in lamps, making a somewhat smoky flame, however. Nothing definite is known concerning the quality of the oil encountered in the Sperry well, but it is said to have been of very good quality and of about 30° Baumé gravity.

FUTURE DEVELOPMENT.

GENERAL STATEMENT.

The conclusions here to be discussed as to the course that future development will take in the McKittrick-Sunset region are based on a belief that the petroleum in the Devils Den district is largely derived from the shales of the Tejon formation and the overlying Oligocene(?) rocks, and that on migration it collects in the sands in the Vaqueros (lower Miocene) formation, which lies above the two formations first mentioned; and that the petroleum in the territory from the Antelope Valley southward is derived from the shales of the Monterey and Santa Margarita(?) formations, and that on migration it collects in the sands at the base of or underlying the Monterey formation—that is, in the sands of the Vaqueros; in sand lenses in the Santa Margarita(?); and also in the porous beds at the base of the McKittrick, which unconformably overlies the older formations. All the conditions indicate that this belief is well founded.

The accumulation of the petroleum and the possibility of its extraction in commercial quantities depend on several prerequisite factors. Among these are the following, briefly stated:

(*a*) An adequate thickness of the shales forming the original source of the oil, to yield commercial quantities of petroleum.

(*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 into 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 the petroleum to pass from the source into the final reservoir, and there to be 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. I) as bounding the possible productive territory are those in which the top of the supposed oil zone has been calculated as within a vertical distance of 5,000 feet from the surface, but excluding some areas (to be mentioned specifically) where the probability of the occurrence of petroleum at any depth whatever decreases with the distance from a given locality. For these exceptional places the depth limit is lessened as the probability of occurrence of petroleum decreases, in order that any locus of points of equal probability may be kept at about equal distance from the line limiting the supposed oil territory. For example, the probability is strong that the zone of the oil sands (Vaqueros or lower Miocene in the locality specified) will be struck at a depth considerably less than 5,000 feet (possibly 3,000 feet) at the southwest corner of sec. 10, T. 26 S., R. 19 E., or less than the depth at which it will be struck at the middle of the north line of sec. 29, T. 25 S., R. 19 E.; but the probability that the zone of the oil sands carries commercial quantities of petroleum is much less in sec. 10 than in sec. 29. To compensate for this greater risk, the line supposed to limit the practicable oil territory is brought equally near to both points, by means of a progressive lessening of the depth limit toward the sec. 10 locality.

A depth of 5,000 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 that have been drilled with a standard rig. It may be possible to go deeper, 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 in commercial quantities will be found in any of the rocks underlying the Vaqueros (lower Miocene), that is, in the Tejon (Eocene), Knoxville and Chico (Cretaceous), or Franciscan formations (see map, Pl. I), while it is quite likely that it will be found in the Vaqueros (lower Miocene) in certain portions of the Devils Den district, and in the Vaqueros sandstone in the Temblor Range south of a line in general coincident with the south line of T. 28 S., and that it will be found also in the basal McKittrick beds throughout the region on the northeastern flank of the Temblor Range south of Media Agua Creek in the eastern part of T. 28 S., R. 19 E. Whether or not the oil will be found in paying quantities in the formations mentioned will depend on the factors enumerated above. 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.

The conclusions reached concerning future development form the basis for the classification of the government land within this region into mineral and nonmineral. This classification is indicated graphically on the map (Pl. I), the mineral land being inclosed by the heavy lines, while that not so inclosed is believed to offer little or no inducement for prospecting for petroleum. A list of the mineral lands will be found on pages 24–31 of this report.

DEVILS DEN DISTRICT.

The tar springs in Little Tar Canyon in sec. 35, T. 23 S., R. 17 E.,[a] and near the north line of sec. 25, T. 25 S., R. 18 E., clearly indicate that the Vaqueros (lower Miocene) sandstone is the most likely reservoir for the accumulation of oil in this district. Oil or signs of oil are, in fact, not known to occur in any other formation within the district except, possibly, at the base of the shale of the Santa Margarita(?) formation. There remains, however, the possibility that the sands above the shales of the Santa Margarita(?) may be more or less impregnated by oil which may have its source in these shales, but as no indications of such an impregnation were discovered by the writers, the predictions are made and the land is classified on the assumption that the Vaqueros zone is the only petroliferous one available in this district.

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[a] See report on the Coalinga oil district (Bull. U. S. Geol. Survey No. 398, p. 228).

The area offering the strongest inducements for prospecting in the Devils Den district lies northeast of the Vaqueros outcrop in sec. 24, T. 25 S., R. 18 E., and thence extends southeastward for a mile or more into sec. 30, T. 25 S., R. 19 E. The factors favoring this particular area are the occurrence of oil in the spring near the middle of the north line of sec. 25, T. 25 S., R. 18 E., and the favorable structural conditions offered by the curving of the formations immediately south and east of this point from a southeasterly to a southwesterly strike. It has been found elsewhere in the developed fields of California that wells located with reference to such structural conditions in petroliferous formations are usually good producers. Both northwestward and southeastward from this favorable territory the probabilities of obtaining oil in commercial quantities become less and less. This is indicated by the lack of direct evidence of petroleum in the outcrops of the Vaqueros sandstone. Westward from the territory outlined on the map as possibly productive, the formations are older than any which carry petroleum in commercial quantities in this district. Further negative evidence is afforded by the Spreckels wells, which penetrate the Cretaceous beds in the eastern part of T. 25 S., R. 17 E., and show no indications of petroleum. Eastward from the outlined territory the dip of the formations places the oil-bearing zone below the depth to which wells can now be profitably drilled.

LOST HILLS DISTRICT.

The area outlined as possibly productive of oil in the region of the Lost Hills is a continuation of a similar belt following the axis of the Coalinga anticline through the Kettleman Hills. The same arguments favoring the occurrence of petroleum in this anticline apply also with modifications to the region of the Lost Hills. The reader is referred to Bulletin 357, pages 120–124, for a discussion of the possibilities for obtaining petroleum in the Kettleman Hills.

The only direct evidence that hydrocarbons are contained in the formations underlying the Kettleman Hills is found at a place known as the Gas Bubble, in the SW. ¼ sec. 19, T. 26 S., R. 21 E., where certain shaly clays are impregnated with a dark-colored material having the odor of oxidized asphaltum. A considerable amount of a peculiar yellowish-orange gummy material was extracted by ether from the shales collected at this locality. It must be said, however, that the possibilities of the occurrence of petroleum in the Vaqueros sandstone underlying these hills appear to diminish as one passes from northwest to southeast, because, in the outcrop of the Vaqueros along Reef Ridge, Pyramid Hills, and the region of Devils Den, the impregnation of the sands is less and less southeastward. It is possible to calculate closely the depth below the surface at which the

Vaqueros sandstone lies in the Kettleman Hills, owing to the excellent outcrops of the overlying formations. In the Lost Hills, however, no outcrops, except beds of unknown age, occur, and for that reason it is impossible to determine with any degree of accuracy the depth of the Vaqueros sandstone below the surface. The general conditions, however, indicate that the axis of the Coalinga anticline is practically horizontal in the region of Light's place, north of Dudley, at the southeastern end of the Kettleman Hills, and it seems likely that this condition continues, with possibly slight variations, as far as the middle of the Lost Hills.

From the middle of the hills southeastward the topographic evidence indicates that the anticline plunges toward the southeast, and therefore it is thought likely that the Vaqueros sandstone in this direction soon reaches a depth unattainable by the drill.

BITTERWATER DISTRICT.

The Bitterwater district includes the Temblor Range south of Antelope Valley as far as Santos Creek, in the southeastern corner of T. 28 S., R. 19 E., as far westward as Palo Prieto Pass. A more or less detailed reconnaissance of this region by the writers failed to disclose any direct evidence of petroleum in the formations exposed. In the sandstone outcrop in the SE. ¼ sec. 6, T. 27 S., R. 19 E., and also in the exposures of the Vaqueros and Tejon formations in sec. 4, T. 28 S., R. 19 E., and at several other localities, the sandstone is stained peculiar reddish, yellowish, and orange tints, believed by some to suggest the former occurrence of petroleum in the beds, but tests of these discolored sands failed to disclose any indications of hydrocarbons. The structural conditions are ideal in portions of this region, and the shales of the Monterey and Santa Margarita (?) formations, which are believed to be the source of petroleum in the fields farther south, are present, but they are of a less purely diatomaceous character than in the region where they are known to yield oil.

TEMBLOR DISTRICT.

The Temblor district lies southeast of the Bitterwater district and northwest of the McKittrick district, and includes the northeastern flank of the Temblor Range and the outlying hills between Santos Creek in the southeastern corner of T. 28 S., R. 19 E., and a line passing westward from a short distance north of Frazer Spring into the head of the Santa Maria Valley in sec. 6, T. 30 S., R. 21 E., and thence northwestward to the crest of the range in sec. 33, T. 29 S., R. 20 E.

In addition to several productive wells in sec. 36, T. 29 S., R. 20 E., indications of petroleum are found in tar springs and asphalt deposits at several localities throughout the district. The most important tar springs occur about one-half mile northeast of the Temblor ranch, in the northern part of sec. 36, T. 29 S., R. 20 E., and the southern part of sec. 25 in the same township. Brea deposits, consisting of shales and sands thoroughly saturated with asphaltum, occur in the northern part of sec. 12, T. 29 S., R. 20 E., in the NE. ¼ sec. 3, T. 29 S., R. 20 E., and in the SE. ¼ sec. 1 in the same township. Oil-impregnated diatomaceous shales overlain by favorable looking oil sand also occur in the E. ½ sec. 7, T. 29 S., R. 21 E. Wells said to have been moderately productive have been put down in the shales at this locality. An oil seepage is also said to occur about 2 miles north of the Temblor ranch, but this was not personally examined by the writers. From the positive evidence offered by the oil springs, brea outcrops, and wells it is quite evident that petroleum in commercial quantities is to be found in the Temblor district.

There are several areas in which the probabilities seem good for the future development of productive wells. One is the territory along the Temblor anticline east of the Temblor wells, in the northern part of sec. 36, T. 29 S., R. 20 E., as far as the broken-up territory in the eastern part of sec. 32, T. 29 S., R. 22 E. It is barely possible that even farther east along this anticline the conditions will be found such as to favorably reward prospecting with the drill, although the fracturing of the surface outcrops indicate rather uncertain conditions in the beds below. Another area along the south flank of the Temblor anticline and fault, south and west of the Temblor wells, also offers inducements for prospecting, especially where the beds have moderately low dips. In fact, it appears likely that the Vaqueros sand is oil bearing beneath practically all the shale area on both sides of the crest of the Temblor Range west and southwest of the Temblor ranch as far as Sandiego Canyon.

Still another locality offering inducements for prospecting is that lying northeast of the SE. ¼ sec. 7, T. 29 S., R. 21 E., as far as the line marking the 5,000-foot limit. The exposures of the tar sands, impregnated shales, and brea deposits and the structural conditions in this particular area all support the theory that commercial deposits of petroleum exist northeast of the oil-sand outcrops. Just how far northwest and southeast these favorable conditions extend is not known, but it seems likely that the McKittrick beds contain more or less petroleum all the way from the region opposite Carneros Spring southeastward to Buena Vista Lake. It is also possible that the beds even farther northwest than in front of Carneros Spring are impregnated. For that reason the line marking the supposed limit of the productive territory has been extended to the eastern part of T. 28 S., R. 19 E., although the probabilities lessen throughout this territory as one goes northwest from the Gould Hills.

The only territory in the district that does not offer inducements for prospecting is the Santa Maria Valley and the region northeast of the line shown on the map as marking the limits of the possible productive territory. The structural conditions in the Santa Maria Valley do not favor the accumulation of commercial quantities of oil, while in the region northeast of the line just mentioned the oil-bearing formations are believed to be more than 5,000 feet below the surface.

McKITTRICK DISTRICT.

The McKittrick district embraces the northeastern flank of the Temblor Range between a line drawn westward a short distance north of Frazer Valley and the central part of the E. ½ of T. 31 S., R. 22 E. It is bounded on the east by a north-south line which goes through McKittrick Pass and divides the Elk Hills from the McKittrick Valley and the hills northeast of it. A detailed study of the underground conditions in the McKittrick Valley leads to the conclusion that the McKittrick oil-bearing formation underlies practically all of the territory northeastward from the present line of productive wells. This line apparently marks the limit of the southwestward extension of the productive oil sands in the McKittrick formation, at least for some little distance. The Vaqueros oil zone undoubtedly underlies all of this territory, and is believed to be within reach of the drill over most of it, although at considerable depths. The test holes that have been put down in the McKittrick Valley and in the hills northeast of it indicate that the oil-bearing beds are not as productive in these lowlands as they are toward the southwest, but that commercial quantities of petroleum are available at reasonable depths. No thorough tests have been made on the northeastern flank of the northernmost anticline in the hills north of McKittrick, but judging by the results obtained by the wells within the hills it does not seem likely that exceptional producers will be obtained in any of the territory in question. An area believed to offer rather unusually favorable inducements for prospecting is that lying along the base of the hills and out into the McKittrick Valley between McKittrick and the Belgian (Temblor-McKittrick) Hills.

BUENA VISTA DISTRICT.

The Buena Vista district includes the region of the Elk Hills and Buena Vista Hills, and lies northwest of Buena Vista Lake, northeast of Midway Valley, and east and southeast of McKittrick Valley. The structural conditions in both the Elk and the Buena Vista hills are practically ideal for the accumulation of petroleum. As the shales of the Monterey and the Santa Margarita(?), which are believed to be the source of the oil throughout this region, underlie the McKittrick beds that form the surface of the hills, the chances for obtaining commercial quantities of petroleum in the district are excellent. Assuming the thickness of the McKittrick formation to be about the same in the hills as it is in the Midway and McKittrick districts—that is, between 1,500 and 2,000 feet—it seems probable that at the axis of the Elk Hill anticline the oil-bearing zone is from 900 to 1,400 feet below the surface. As the edge of the hills is approached the dip of the beds carries the formations down, so that wells drilled near the edge would have to go at least 600 or 800 feet deeper than they would near the summit of the hills. Furthermore, the dip, at least on the southwest flank of the main anticline, steepens perceptibly toward the edge of the hills, and this would still further increase the depth to which the wells would have to be put down to penetrate the oil-bearing zone.

At least two of the test holes that have been drilled in the Buena Vista Hills have struck large quantities of gas in sands below thick clay deposits. As these wells are both near anticlinal axes the gas strikes indicate one of two things to the writers. Either the gas is the accumulation above oil that lies lower down the dip in the same stratum, or else the gas has been able to penetrate higher beds than could be penetrated by the oil from which it is believed to be derived, and the oil lies in the same formation as that containing the gas but in lower beds. In either case the occurrence of the gas is believed to be indicative of the presence of oil in the hills under discussion.

The arguments favoring the occurrence of petroleum in the Elk Hills are also applicable to the formations in the Buena Vista Hills, the anticlines apparently offering the strongest inducements because of the less depths at which the supposed oil-bearing formations would be encountered, and also because as a general rule the greatest accumulations of petroleum occur near the axes of anticlines.

A particularly advantageous locality for exploitation is that southeast of the region of the Belgian (now Temblor-McKittrick) wells in sec. 34, T. 30 S., R. 22 E. Not only are there indications of petroleum along the southeastward continuation of the Dabney anticline, but the dips on the flanks of this anticline support the theory that it is fractured little, if any, and therefore is more likely to retain its petroleum than it would be were it crushed and fractured. The flat country between the Buena Vista Hills and the hills southwest of the McKittrick Valley is covered by recent deposits which mask the underlying structure. It appears quite likely, however, that the anticlines which plunge southeastward under this masked area are continued in the anticlines found in the Buena Vista Hills, and in some instances this supposed relation has been shown on the map (Pl. I). Assuming therefore that the conditions are continuous across these flats, it is almost certain that if petroleum is encountered on the flanks of these anticlines it will also be found beneath the flats along the continuation of the same anticline.

The only surface evidence of the occurrence of petroleum in Buena Vista Hills is the oxidized asphalt deposits in sec. 11, T. 32 S., R. 24 E. These occurrences strengthen the belief that commercial deposits of petroleum underlie the hills. In selecting points for development work the localities where the beds dip steeply should be avoided and those chosen where the dips are moderate and the conditions less favorable for faults and sharp flexures.

MIDWAY DISTRICT.

REGION WEST OF DEVELOPED MIDWAY FIELD.

In the Midway district petroleum occurs in all of the formations later than the Eocene. It is known to occur in commercial quantities in the McKittrick, for the Midway and Sunset fields secure their oil from the sands of this formation, and in favorable localities it will probably be found in commercial quantities in the Vaqueros sandstone, at the base of the Monterey shale, and in the Santa Margarita(?). The evidence on which this belief is founded is (*a*) the occurrence of oil in wells penetrating the Monterey and Vaqueros on the southwest flank of the range opposite Midway and on the northeast flank south of Crocker Spring, (*b*) the occurrence of oil in outcropping sands in the basal Monterey or upper Vaqueros at several localities in the canyons south and southwest of Crocker Spring, (*c*) the occurrence of indications of petroleum in the same zone along the entire northeast front of Temblor Range from Crocker Spring to the Sunset district, especially where the canyons cut the anticlinal axes, and (*d*) the locally favorable structural conditions throughout the region in which the evidences of oil occur. It is impossible in a report of this kind, based on a reconnaissance covering many hundreds of square miles, to go into details concerning the degree of probability of securing commercial quantities of petroleum in each quarter section. The most that can be said is that wherever it is calculated that the sands in the top of the Vaqueros formation or bottom of the Monterey can be reached at a depth of less than 5,000 feet from the surface, there the land is classified as mineral and the probabilities of encountering oil are believed to be worth considering. In a region of complex structure like that of the Temblor Range the conditions affecting the accumulation of oil differ widely within short distances, so that a detailed study of each particular locality is necessary before a proper conclusion can be drawn as to the depth of the oil-bearing zone below the surface. It may be said in general, however, that the most favorable localities are near the axes of the anticlines, especially those with relatively low dipping flanks. Another favorable locality is along any line which marks a change from a low to a steep dip, both dips being in the same direction. This is simply a special form of the anticline in which the plane of the axis is oblique instead of vertical, as in a symmetrical anticline. An anticline which appears to fulfill these favorable conditions at one place or another along its course is the one lying one-half to 1 mile northeast of the crest of the range in the region southwest of the developed part of the Midway district. Other anticlines in the territory under discussion also appear favorable at one place or another, these particularly favorable localities usually being indicated on the map by anticlines with low dips. Another factor that must not be overlooked in calculating the probabilities of securing positive results at any particular point is the position in the formation of the beds exposed at the surface at the point in question. In the anticline mentioned above, which runs parallel with and not far from the crest of the range, the beds near the axis are usually close to or even practically coincident locally with the base of the Monterey, so that moderate depths should suffice to disclose the oil sands. Farther northeast and down the flank of the range the sands are buried deeper below the surface. In those localities where the dip of the strata is steep deep drilling will be necessary.

REGION NORTH AND NORTHWEST OF THE DEVELOPED TERRITORY.

The Midway Valley, locally known as the "Midway flats," offers reasonable inducements for exploitation. The hills southwest of the valley have indisputable evidence of their petroleum contents in the producing wells and outcrops of oil-bearing beds, while in the hills to the northeast there is also evidence indicating the petroliferous character of the underlying formations.

Two factors enter into the question of probability of obtaining productive wells in this valley. One is the question of the thinning toward the northeast of the coarse sand lenses which act as the reservoirs for the oil in the territory already tested; the other is the question whether or not water in the petroliferous zone will interfere with the successful operation of the wells. As to the first question, it seems likely that the coarser beds become thinner toward the northeast, but this thinning may be in part compensated for by the greater impregnation of the sands. The question of the control of the water is one that can be answered only after test holes are carefully put down. It has been the experience in analogous structural positions in other localities to find that the water in the beds increases toward the center of the syncline, and, as the Midway Valley is in a general way a great syncline, it is more than likely that the beds underlying it will be found to contain more water than the same beds nearer the edge of the valley.

Owing to the covering of the oil-bearing McKittrick formation by alluvial fans in the region northwest of the developed territory, it is impossible to predict the structural conditions with any degree of certainty. Evidence offered by the productive wells and the outcrops of the beds nearest the valley in the region north of the south line of T. 31 S. clearly indicates that the oil-bearing McKittrick formation continues northwest under the valley to the region east of the tank house, in sec. 17, T. 31 S., R. 22 E.

SUNSET DISTRICT.

REGION SOUTH AND SOUTHWEST OF THE DEVELOPED TERRITORY.

The region south and southwest of Sunset is occupied by a core of supposed Vaqueros (lower Miocene) sandstone along the axis of the Potts anticline, above this sandstone a thickness of 2,900 feet of siliceous and earthy Monterey shale, and still higher up the diatomaceous shale and intercalated sandstones of the Santa Margarita(?) formation. Several wells have been put down in this area, including the Manhattan near the center of sec. 11, T. 11 N., R. 24 W.; the Sunset Queen, near the middle of the east line of the NW. ¼ sec. 14, T. 11 N., R. 24 W.; the Potts well, in the southeast corner of sec. 23, T. 11 N., R. 24 W.; and the Sunset Petroleum and Refinery well, in the northwest corner of the NE. ¼ sec. 29, T. 11 N., R. 23 W. With the exception of the Sunset Queen, in which a little doubtful oil sand was reported, these wells struck no oil, but plenty of water. The Potts well is said to have been drilled to a depth of 1,361 feet and to have encountered water at 400 and 1,200 feet, the latter horizon yielding a flow of 40 to 50 barrels of salt water per day. The strata penetrated were hard quartz sands, with occasional thin layers of dark shale, the latter more abundant from 600 feet down. The other wells mentioned penetrated blue shale, with many hard streaks and occasional soft sands or water sands.

It is the opinion of the writers that this territory has not been thoroughly tested, and that the probabilities for finding oil in commercial quantities are good over certain areas in it. The oil is believed to be in the sands at the top of the Vaqueros and base of the Monterey; in other words, in the transition zone of alternating sandstone and shale between the two formations. The reasons for this belief are that seepages are found in this zone at several points along its line of outcrop in this particular territory; and, furthermore, that this is the horizon that yields the oil at the Smith and Erume wells, on the southwest flank of the Temblor Range opposite McKittrick. It is thought that the oil contained in the beds of this zone is lighter in gravity than that occurring in the McKittrick formation (Sunset oil sands), and even than that found in the same formation as the last in the Midway district. The reasons for this belief are the quality of the oil found at the outcrop of the zone in the southern part of sec. 23, T. 11 N., R. 24 W., the quality of the oil found at the Erume wells at the same horizon, and the analogous position of the zone as regards the overlying siliceous diatomaceous shales (in which the oil is believed to originate) to certain of the oil sands of the Santa Maria district.

The areas best suited for testing the zone are those in which it would be struck at depths ranging from 600 to 1,200 feet and downward, and include strips on both sides of the Potts anticline. The width of these strips and their position relative to the axis of the anticline vary from point to point, depending on the dip of the beds. Some of these dips are shown on the map (Pl. I). In general, it may be said that the conditions are more favorable in those areas where the dip of the strata is least.

REGION EAST OF SUNSET.

The geologic conditions affecting the region along the base of the foothills and extending out into the flats east of the developed Sunset field indicate an indefinite eastward and southeastward extension of the field. The formations believed to be the source of the oil and also those acting as reservoirs for it undoubtedly underlie practically all of the region in question. Furthermore, evidence favoring its presence and conditions favoring its accumulation appear to be good. From a practical point of view the governing factor relating to its recovery appears to be the depth at which the deposits lie. The map (Pl. IV), indicating the position of the top of the oil-bearing zone by contours, furnishes the desired data for the developed portion of the field and the territory immediately adjacent. The flats east of the contoured area are affected by two lines of structure, the north-northeast dipping monocline flanking the foothills of the Mount Pinos Range, and the Thirty-five anticline, which passes slightly south of east into the flats from the southern part of sec. 35, T. 12 N., R. 24 W. From the available data at hand it is believed that the axis of the last-mentioned anticline plunges east with a dip less than 12°. This would carry the top of the oil zone (zone B) to a depth of 5,000 feet below the surface at the top of the anticline on the northern part of sec. 10, T. 11 N., R. 23 W., as shown on the map (Pl. I). The prospects for productive wells are believed to be good along this anticline at least as far out on the flat as the point just mentioned, and possibly farther, for the dips tend to lessen as the beds approach the valley. It is therefore possible that the productive zone is actually wider than is indicated by calculations based on dips taken near the hills. The sharp upturning of the beds in secs. 17 and 18, T. 11 N., R. 23 W., and southeast of the latter, indicate a narrowing of the possible productive territory north of these sections. The theoretical location of the Phœnix syncline, which marks the lowest portion of the productive beds between the hills on the south and the Thirty-five anticline on the north, has been calculated from all available data and located as shown on the map (Pl. I). In general it may be said that difficulties with water will increase with approach to the axis of the syncline; furthermore, it is believed that the productiveness of the wells will be found to decrease eastward from the vicinity of Hazelton, at least for about 3 miles.

CARRIZO PLAIN DISTRICT.

The Carrizo Plain district includes the region southwest of Palo Prieta Pass as far as the southeast corner of T. 28 S., R. 18 E., and the region southwest of the crest of the Diablo Range southeastward from the same corner. It embraces the Carrizo and Elkhorn Plains, the northeastern flank of the Caliente Mountains, and the fringe of hills along the southwestern edge of the Carrizo Plain. A very hasty reconnaissance of the hills southwest of the Carrizo Plain as far south as Painted Rock ranch, in sec. 30, T. 31 S., R. 20 E., discloses evidence of petroleum at only one point. This was in the northern part of sec. 23, and the southern part of sec. 14, T. 29 S., R. 17 E., where an oil sand outcrops at the base of the Santa Margarita (?) formation. The sand here was not over 10 feet thick, consisted of coarse quartz grains, and showed a tendency toward concretionary structure. It immediately overlies the Monterey shale, which outcrops in the axis of an anticline passing through the locality mentioned. This occurrence of oil sand indicates that petroleum in small amounts occurs at the base of the Santa Margarita (?) formation throughout at least a portion of the Carrizo Plain region, north of the southern part of T. 29 S., R. 18 E.

It is not thought probable that deposits of economic importance will be encountered in this region, as the structural conditions are more or less unfavorable owing to the numerous faults that affect the formations adjacent to the plain. No other indications of petroleum were found on the southwestern flanks of Temblor Range north of an east-west line through the mouth of Sandiego Canyon. Numerous indications of petroleum are found in the Vaqueros and overlying formations southeast of Sandiego Canyon, along the flanks of the Temblor Range, and it appears highly probable that commercial deposits of petroleum occur at many places along the anticlines in this region. The anticline which begins about half a mile south of Sandiego Joe's—that is, at the southeast corner of sec. 8, T. 30 S., R. 20 E.—and passes southeastward along the flanks of the range (see map, Pl. I) has been tested at two different localities over a mile apart, at the

Smith wells near the corner of secs. 22, 23, 26, and 27, T. 30 S., R. 20 E., and a mile northwest of that point.

The Vaqueros also yields oil near the surface at the Erume wells in the southern part of sec. 22, T. 31 S., R. 21 E. The peculiar pinkish color indicative of petroleum is also found at practically all the outcrops of the Vaqueros in the anticlines along this part of the range.

Bearing in mind these favorable indications, it appears probable that wells sunk through the overlying Monterey shale and tapping the Vaqueros sandstone at advantageous localities will yield petroleum. As the petroleum produced by the shallow holes so far sunk is particularly good, ranging as high as 28° Baumé, it seems probable that oil wherever obtained from the Vaqueros will be excellent. As the conditions here mentioned as favorable continue practically uninterrupted along the range as far southeast as the region back of Sunset, it seems likely that prospecting in favorable localities in the Carrizo Plain district should secure positive results. Owing to the complex folding and accompanying faulting which affects this region, even to a greater extent than the northeastern flank of the range, detailed examinations of any particular area should be made before predictions are attempted. On the accompanying map (Pl. I) the principal lines of structure are indicated. It is thought by the writers that the anticlines with low-dipping flanks offer the best inducements for exploitation.

PRODUCTION.

The following table of production of the McKittrick, Midway, and Sunset fields by calendar years from 1900 to 1908 was compiled by Miss Belle Hill, under the direction of Dr. David T. Day, of the United States Geological Survey:

Barrels of oil produced in McKittrick, Midway, and Sunset fields, California, 1900–1908.

Year.	McKittrick.	Midway.	Sunset.	Total.
1900				892,500
1901	430,450	4,235	188,600	623,285
1902	619,296	3,048	[a] 167,558	789,902
1903	658,351	[a] 5,000	[a] 250,000	913,351
1904				
1905	276,171	11,033	302,701	588,905
1906	531,185		409,335	940,520
1907	1,944,671	134,174	567,175	2,646,020
1908	2,517,951	410,393	1,556,263	4,484,607

[a] Estimated.

STORAGE.

The storage facilities of the McKittrick field consist of three 55,000-barrel tanks, in addition to a dozen or more earthen settling and temporary storing reservoirs and several small settling and temporary storing tanks.

The storage capacity of the Midway field is practically limited to the tanks of the Standard Oil Company, at their pumping plant in the edge of the Buena Vista Hills.

The storage facilities in the Sunset field consist largely of open earthen reservoirs. Two covered earthen reservoirs, with a total storage capacity of about 100,000 barrels, and four or five metal tanks holding all told about 150,000 bârrels, comprise the remainder of the storage room.

TRANSPORTATION.

Two railroads and one pipe line carry oil from the McKittrick-Sunset region, and two other pipe lines to accommodate the same territory are now in course of construction. A branch of the Southern Pacific Railroad joins McKittrick and Olig with the main lines of the Southern Pacific Company and the Atchison, Topeka and Santa Fe Railway at Bakersfield, while the Sunset Western Railroad, owned jointly by the Southern Pacific Company and the Atchison, Topeka and Santa Fe Railway, joins Midoil, Moron, Monarch, and Hazelton with the same roads at the same junction. Most of the oil in the McKittrick and Sunset fields and a part of the product of the Midway field is carried in tank cars on these branch lines. An 8-inch pipe line of the Standard Oil Company joins Bakersfield and the pump station on the edge of the Buena Vista Hills in sec. 1, T. 32 S., R. 23 E. Branch lines run from this station to the McKittrick and Midway fields. The Producers Transportation Company now has in course of construction an 8-inch line joining the Sunset, Midway, and McKittrick fields with Port Harford. This line is joined by a similar one from Coalinga at the Antelope Valley station, and a branch from McKittrick runs to the Kern River field, near Bakersfield. The Associated Oil Company is also constructing a pipe line from Sunset through the Midway, McKittrick, and Coalinga fields to its main Kern River and Port Costa line at Mendota.

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